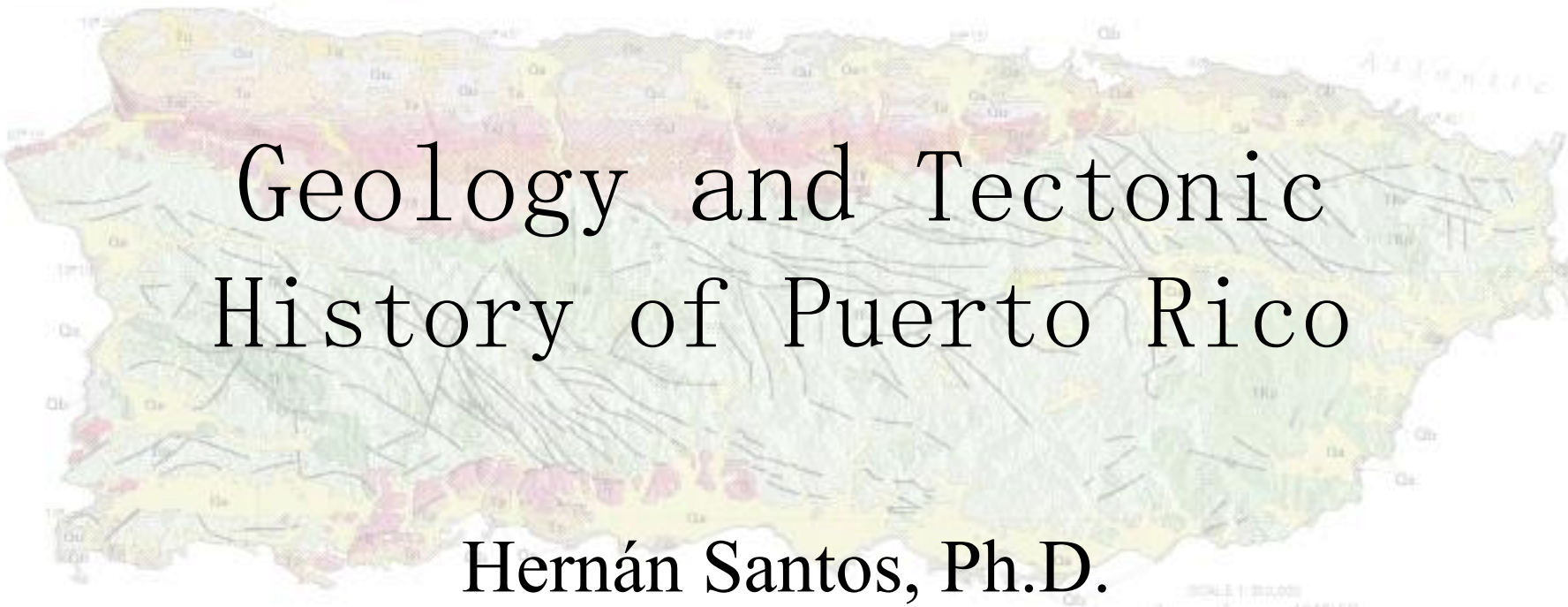


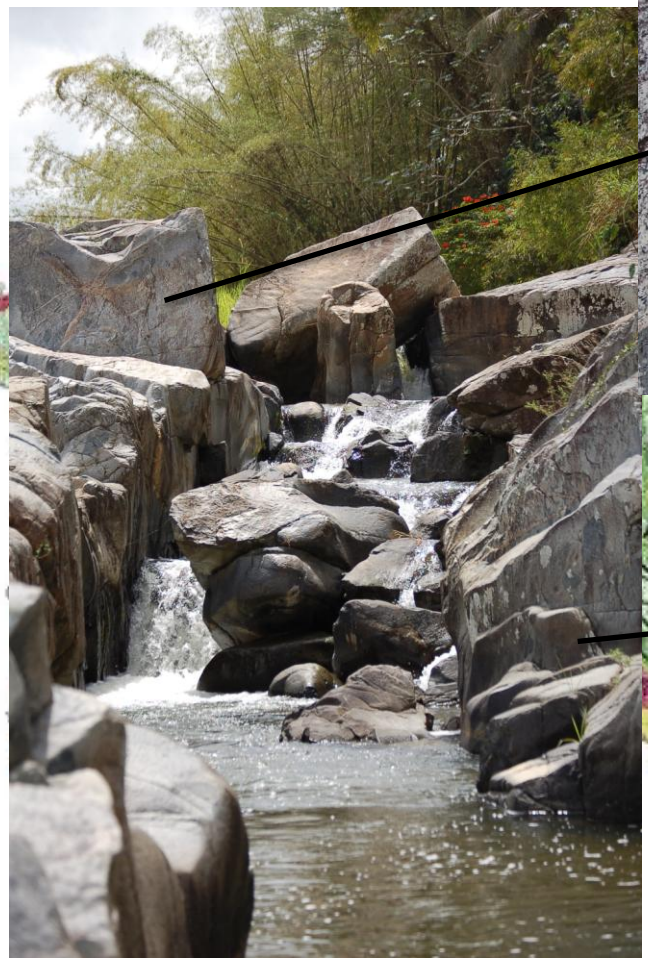
Geology and Tectonic History of Puerto Rico

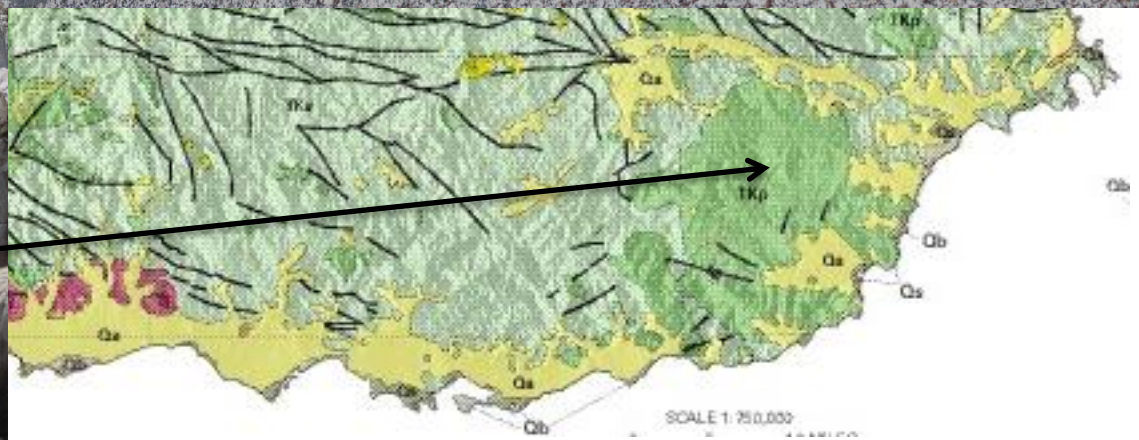
Hernán Santos, Ph.D.

Department of Geology

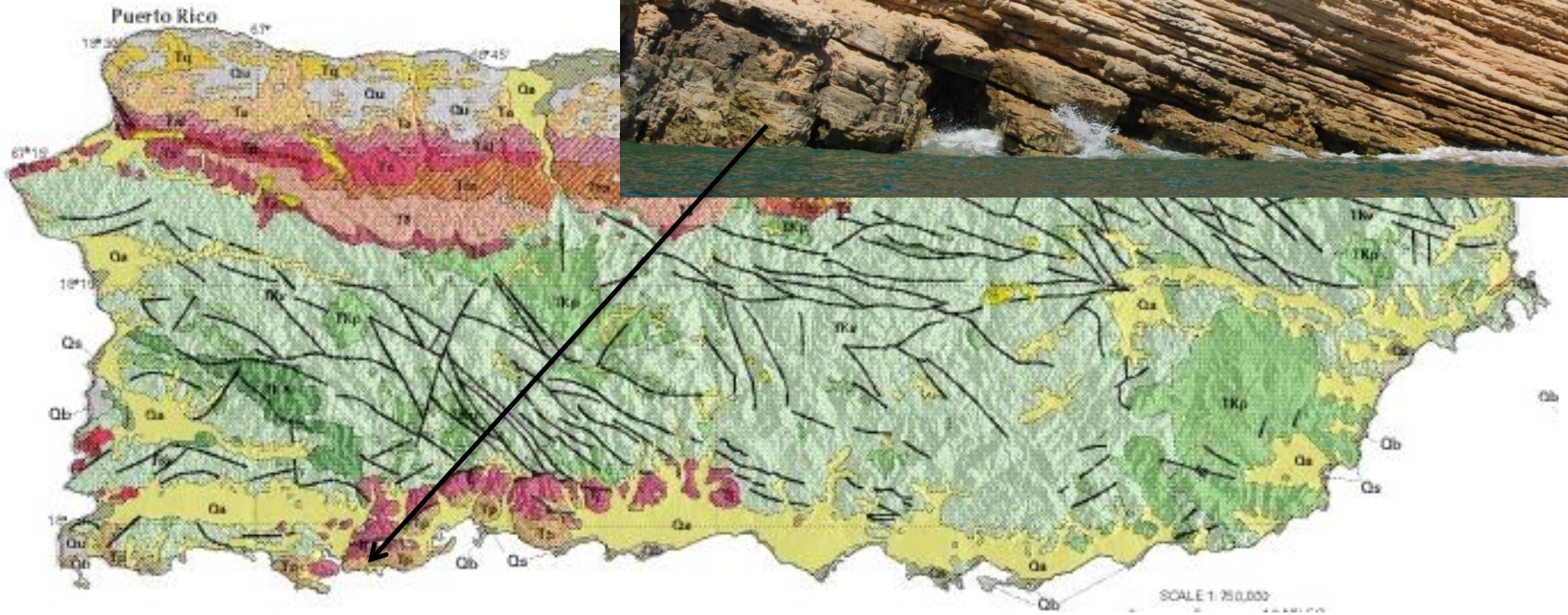
University of Puerto Rico - Mayagüez

Geology

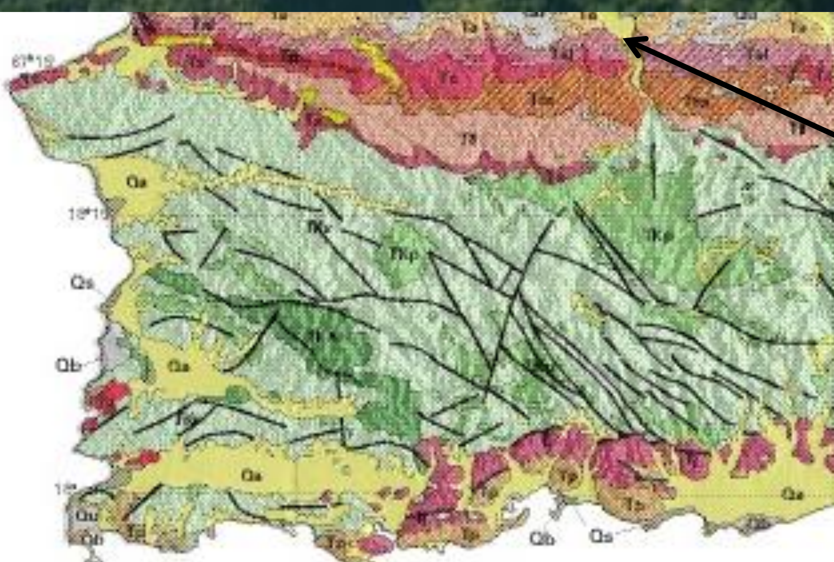




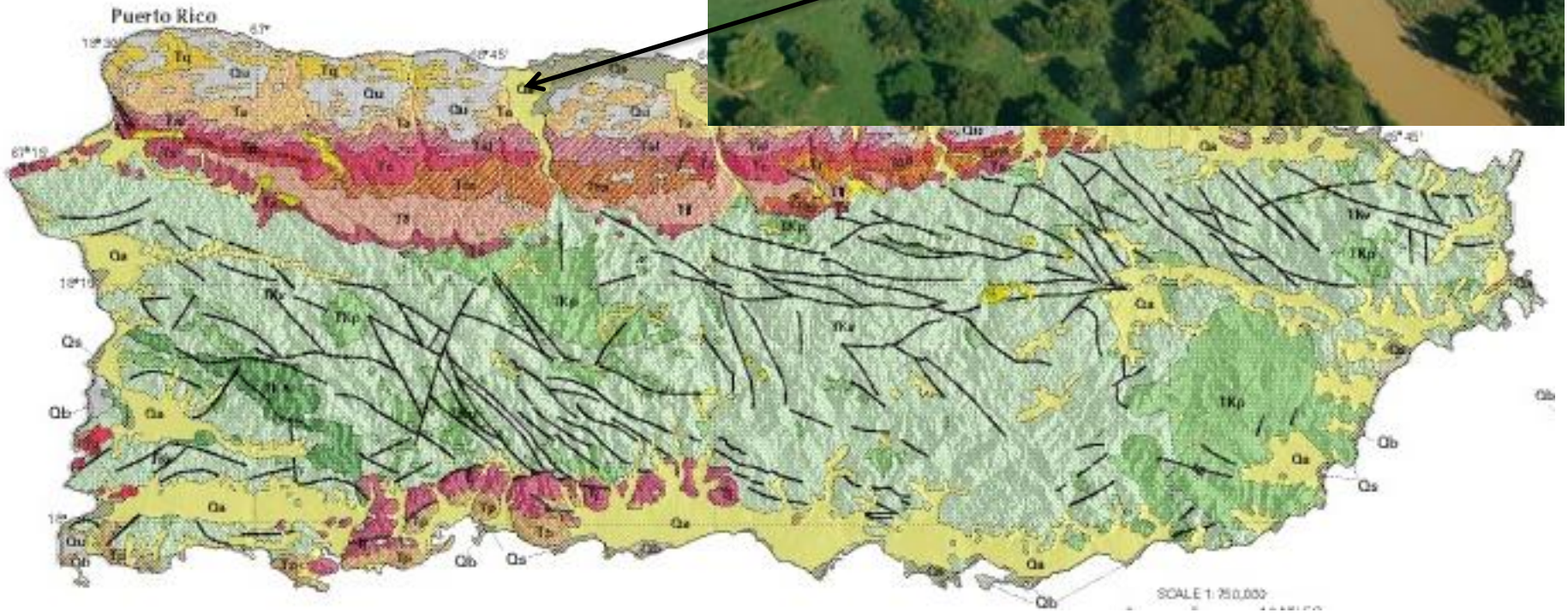
Geology



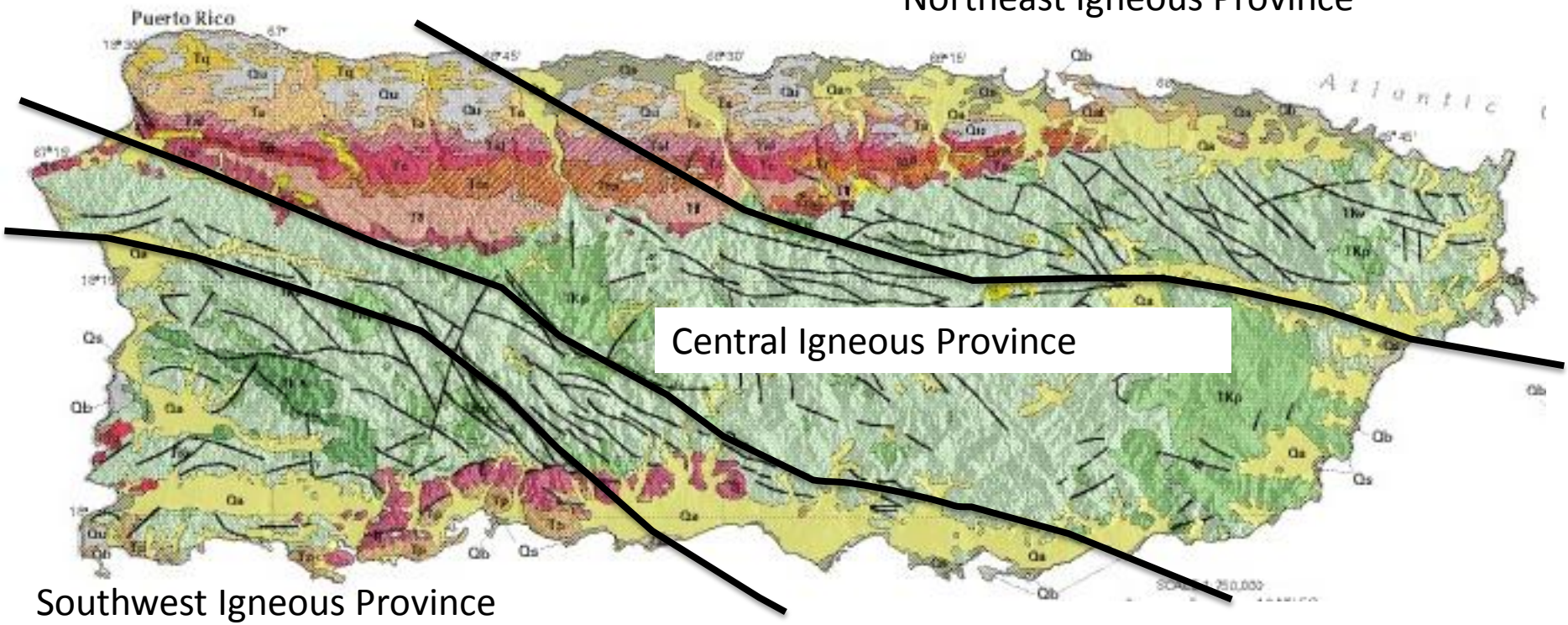

Qb
Atlantic


Qa
Qs
Qb
Qa
Qa
Qb
Qs

Geology of



Geology of Puerto Rico



Northeast Igneous Province

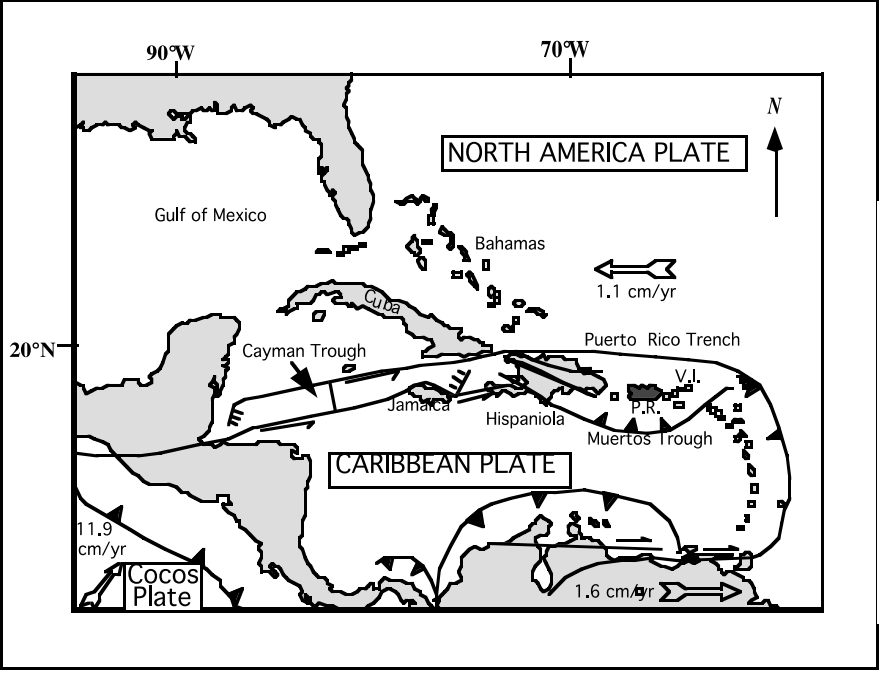
Central Igneous Province

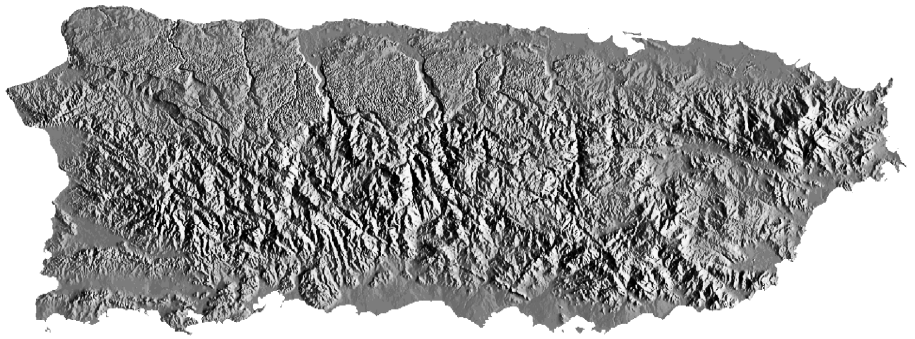
Southwest Igneous Province

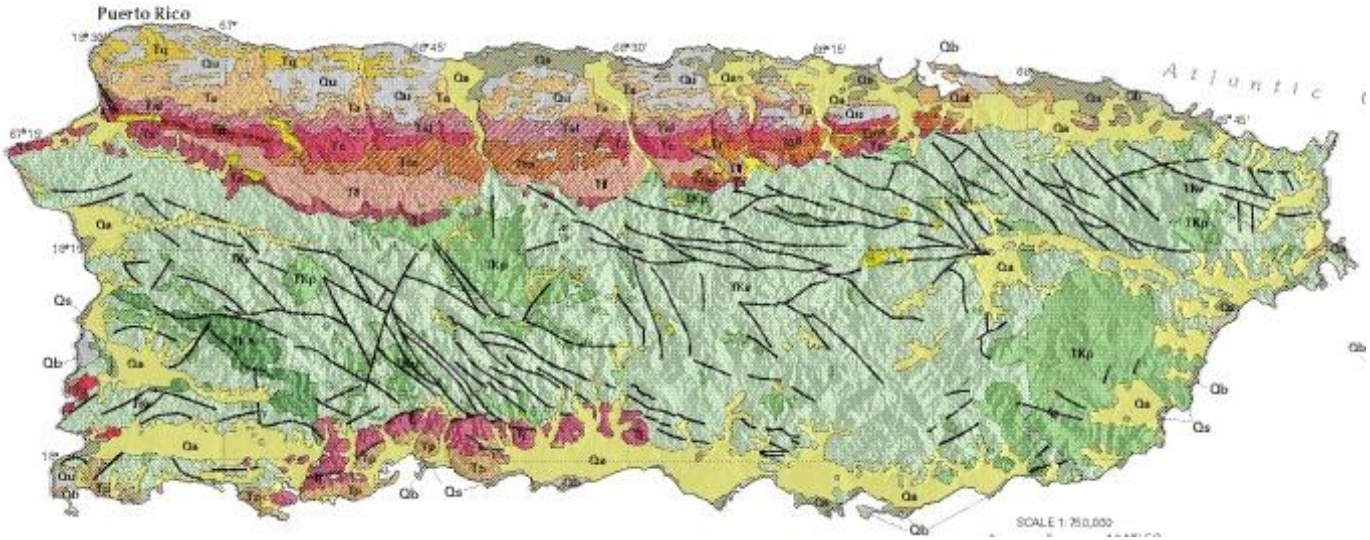
USGS-HA730-N

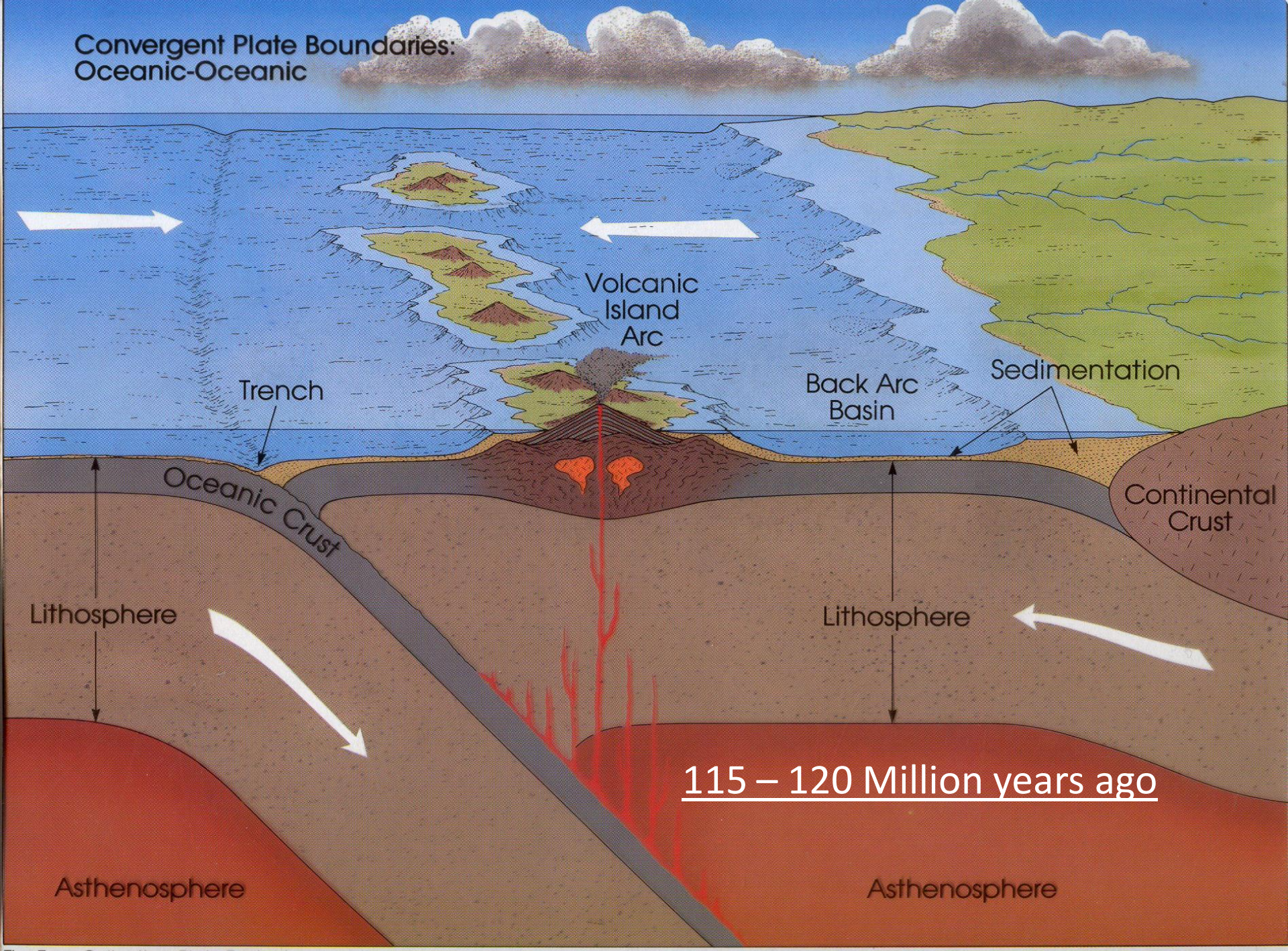
Eocene Basinal volcanic flows and sediments

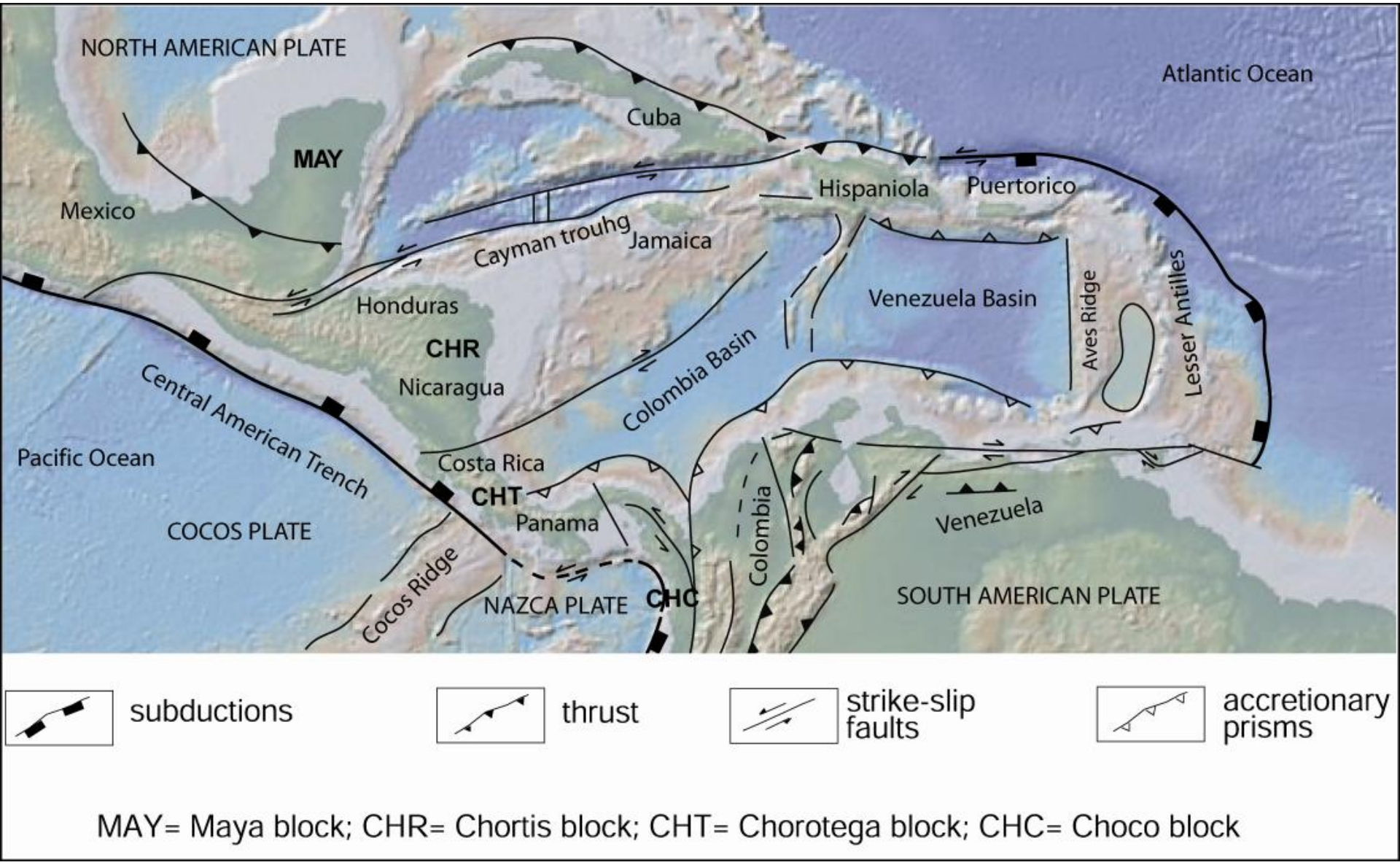
Tectonic Map of the Caribbean



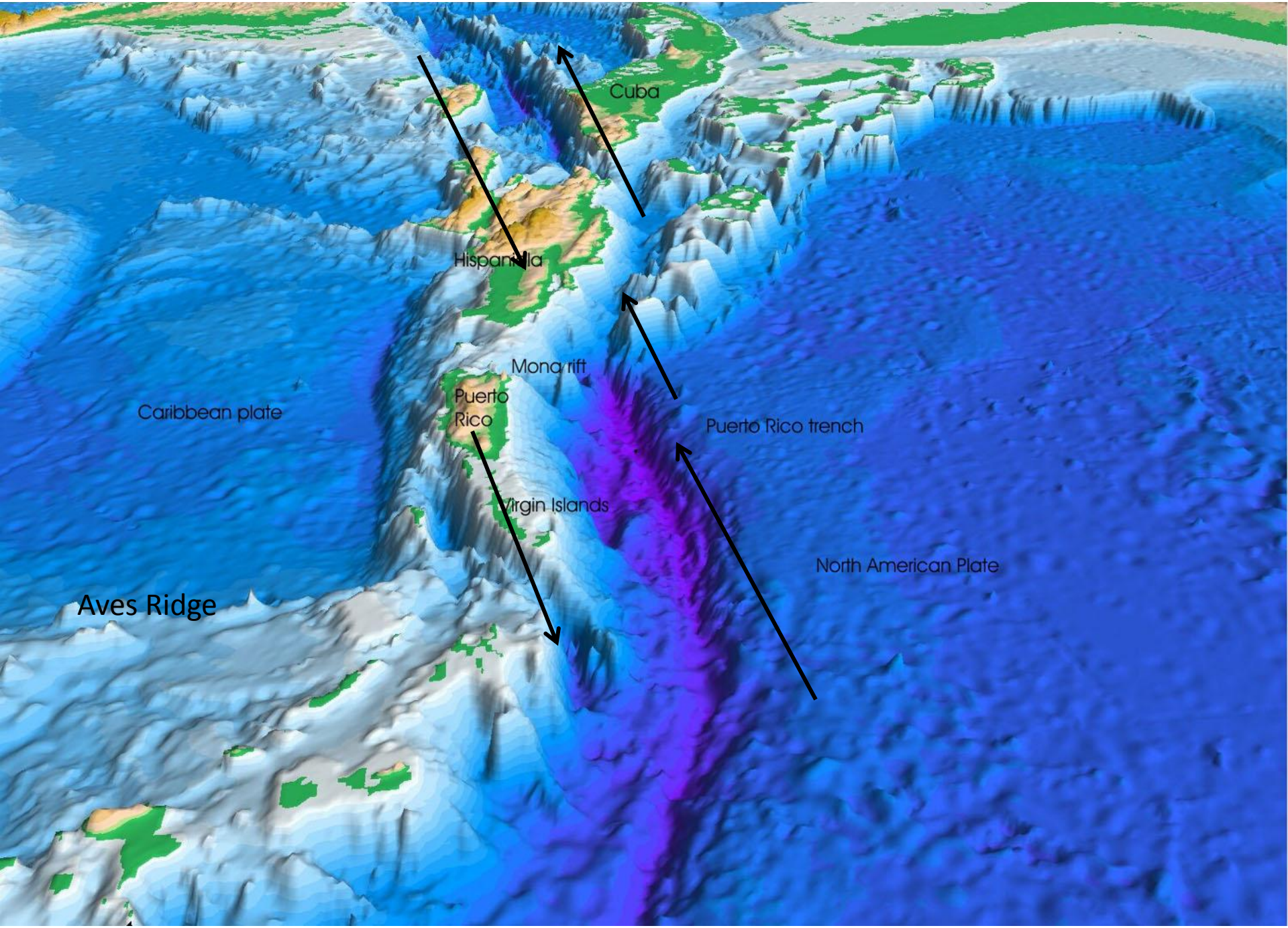




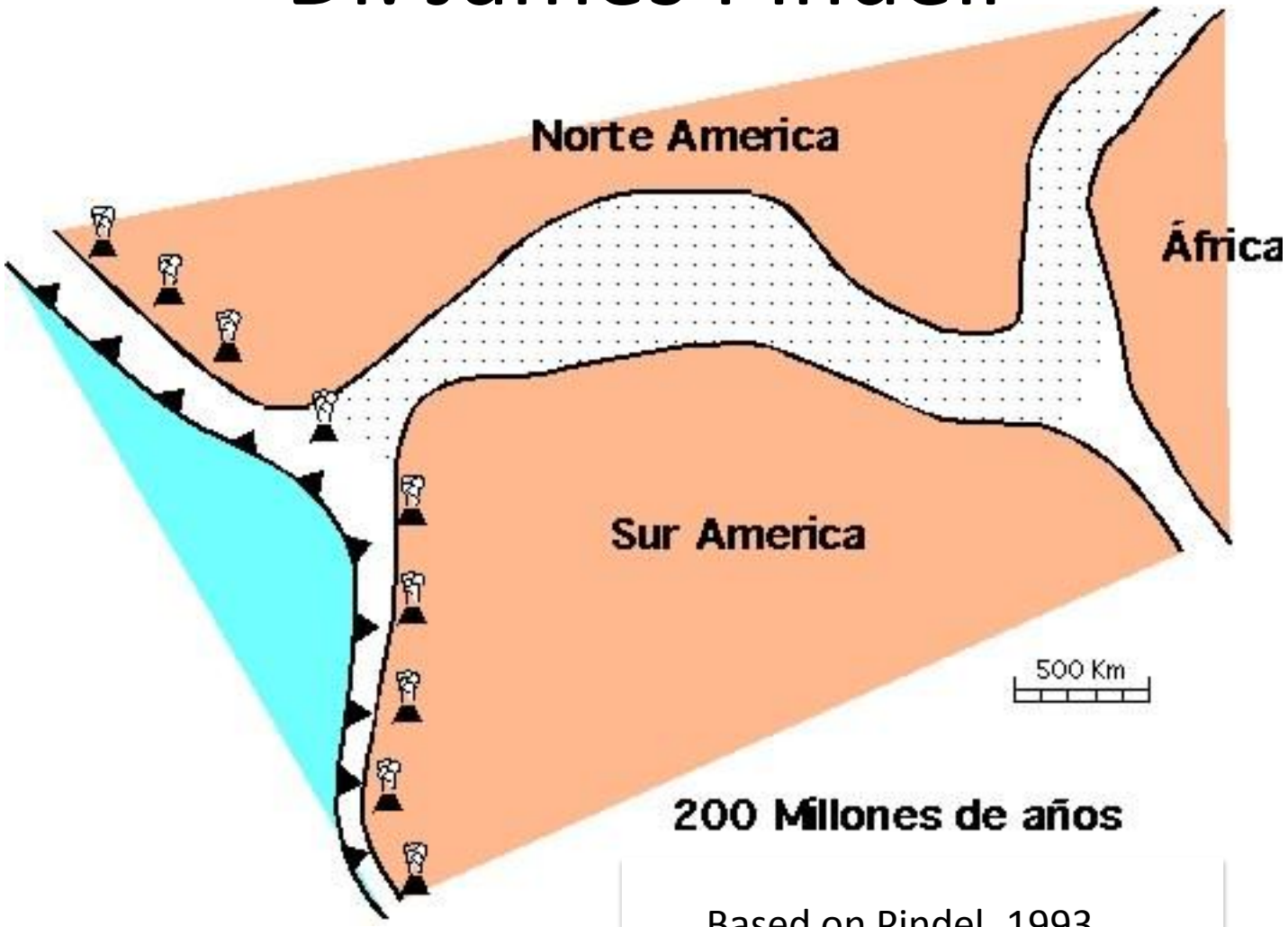




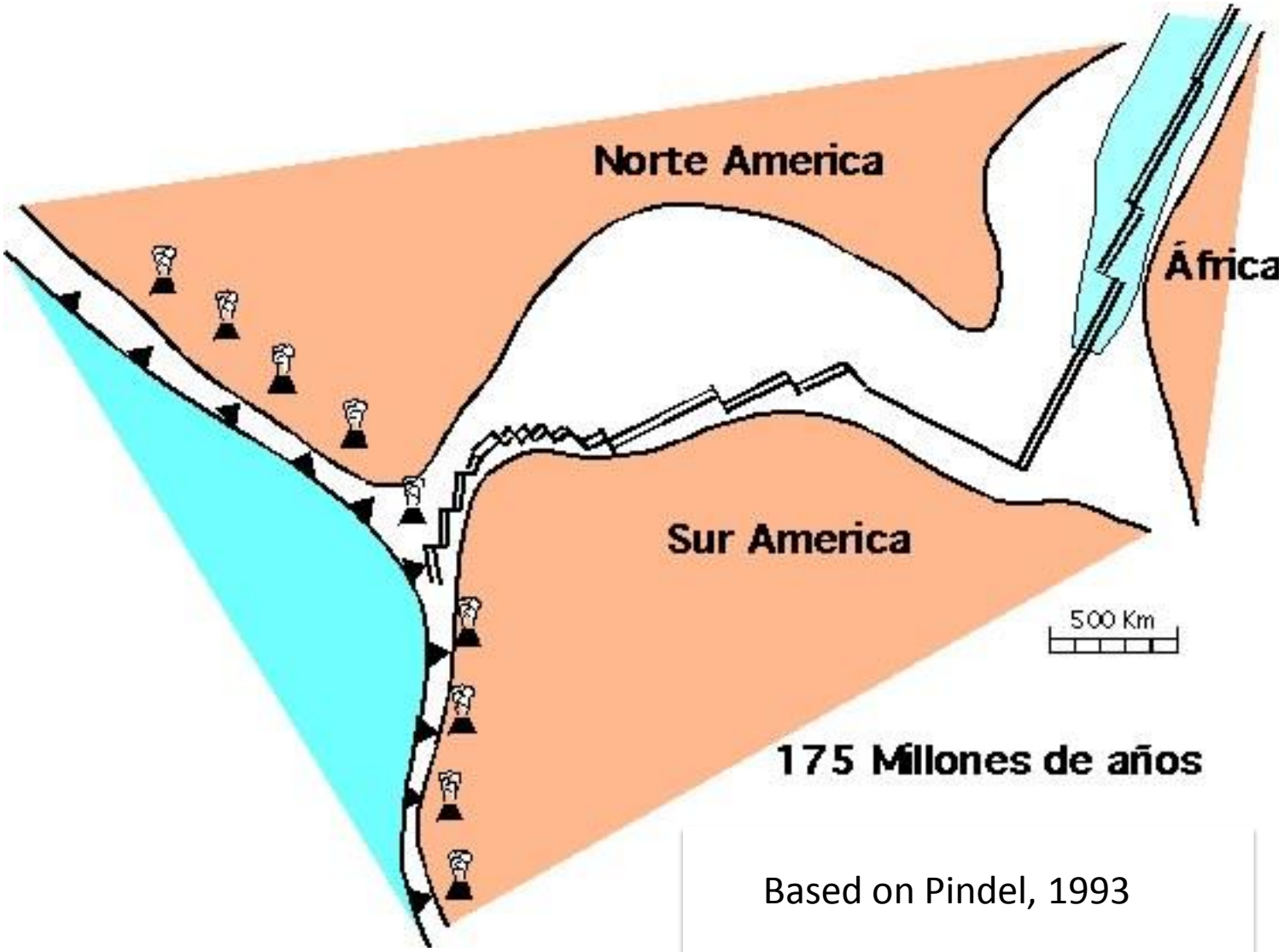
Giuseppe Giunta and Silvia Orioli


Cuba
Hispaniola
Mona rift
Puerto Rico
Caribbean plate
Puerto Rico trench
Virgin Islands
North American Plate
Aves Ridge

Tectonic History of the Caribbean
Dr. James Pindell



Based on Pindel, 1993



Based on Pindel, 1993

Norte America

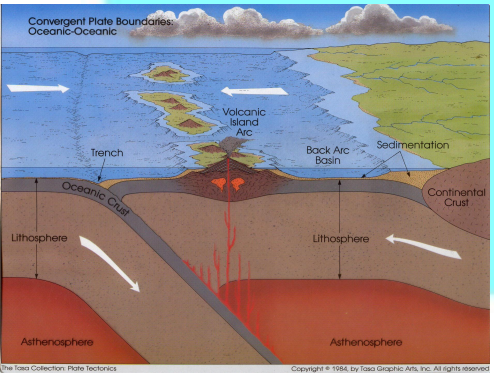
Volcanismo

África

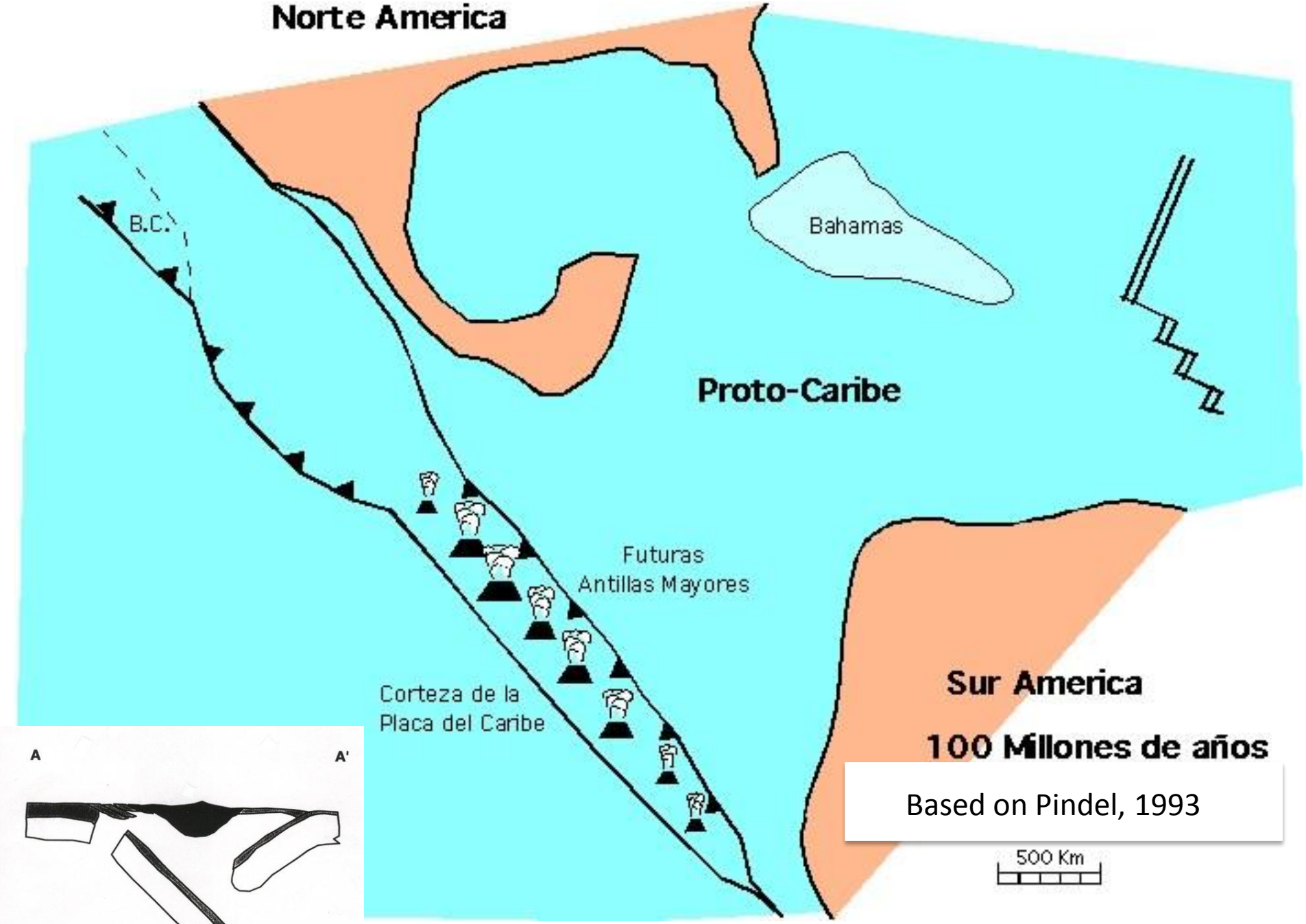
Sur America

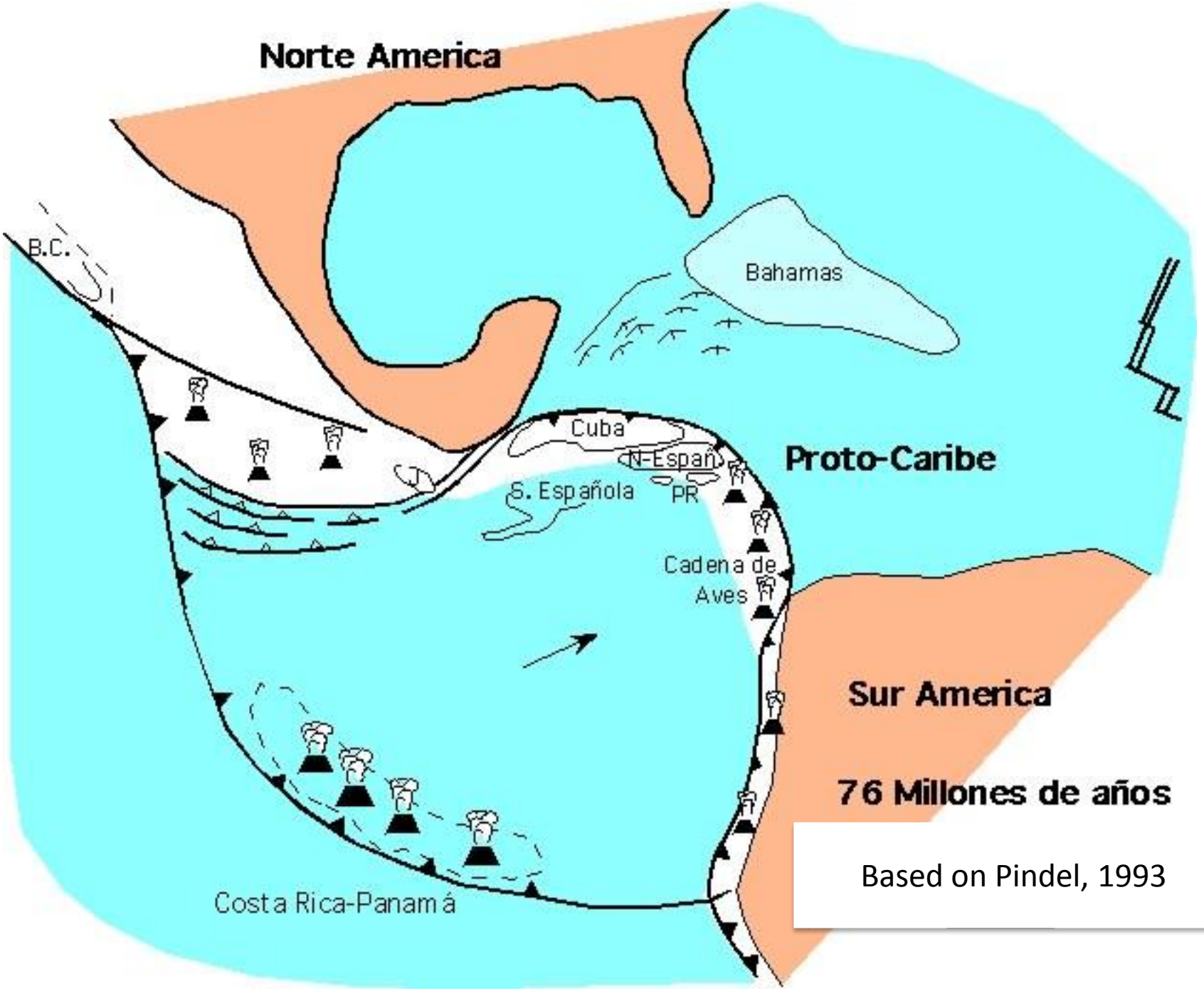
500 Km

130 Millones de años

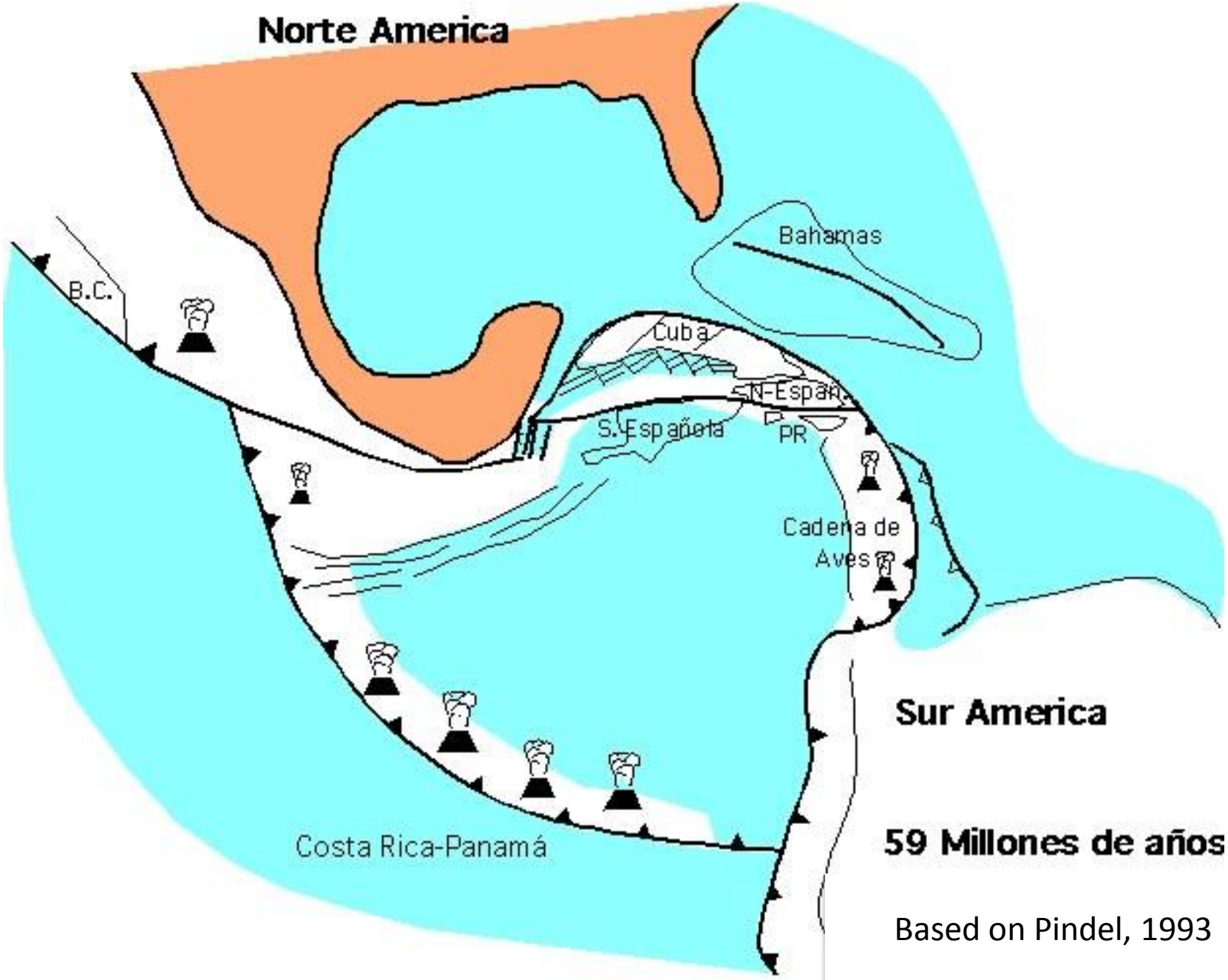


Based on Pindel, 1993

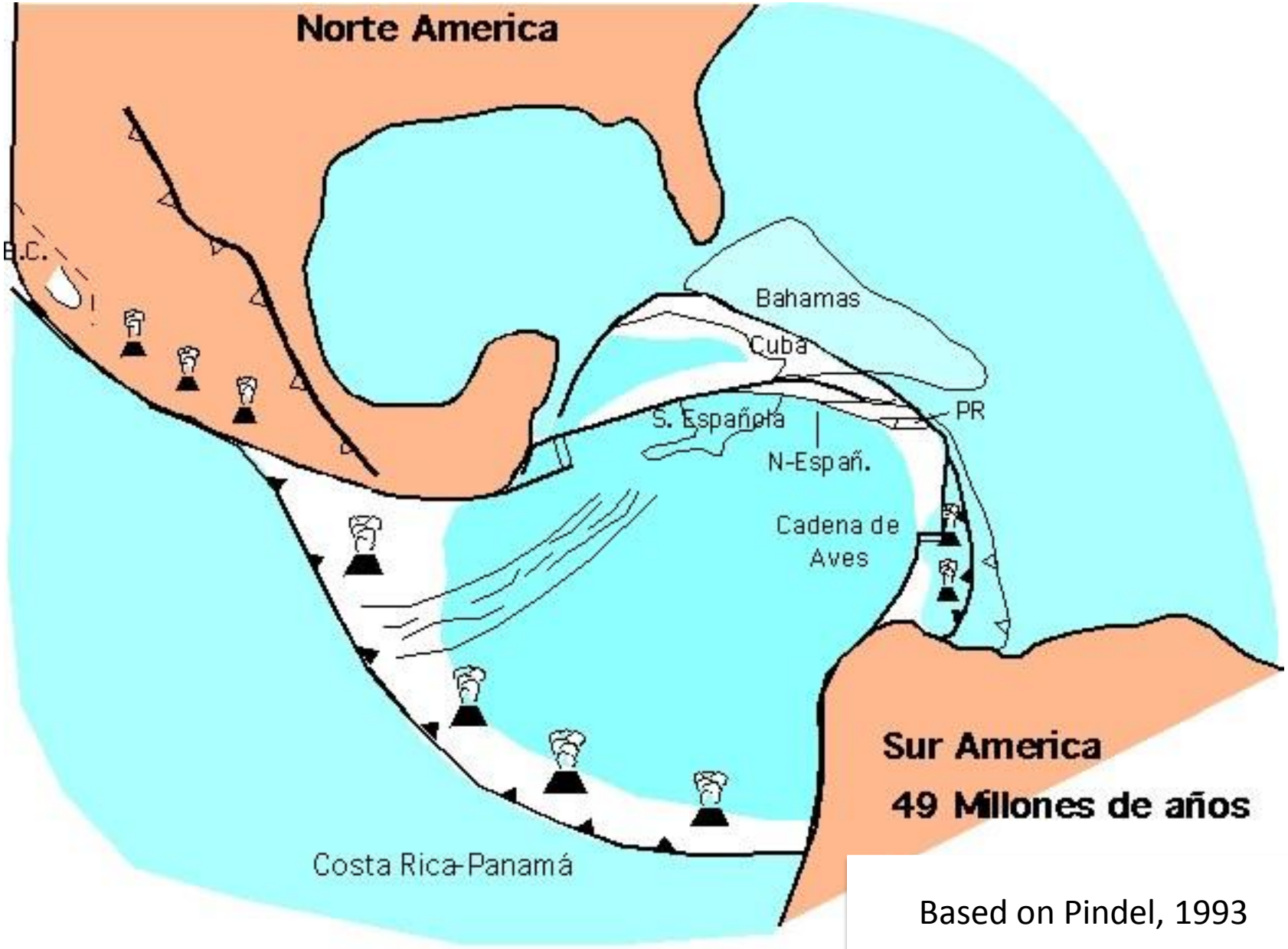

Norte America
B.C.
Bahamas
Proto-Caribe
Futuras
Antillas Mayores
Corteza de la
Placa del Caribe
Sur America
100 Millones de años
Based on Pindel, 1993
500 Km
A
A'



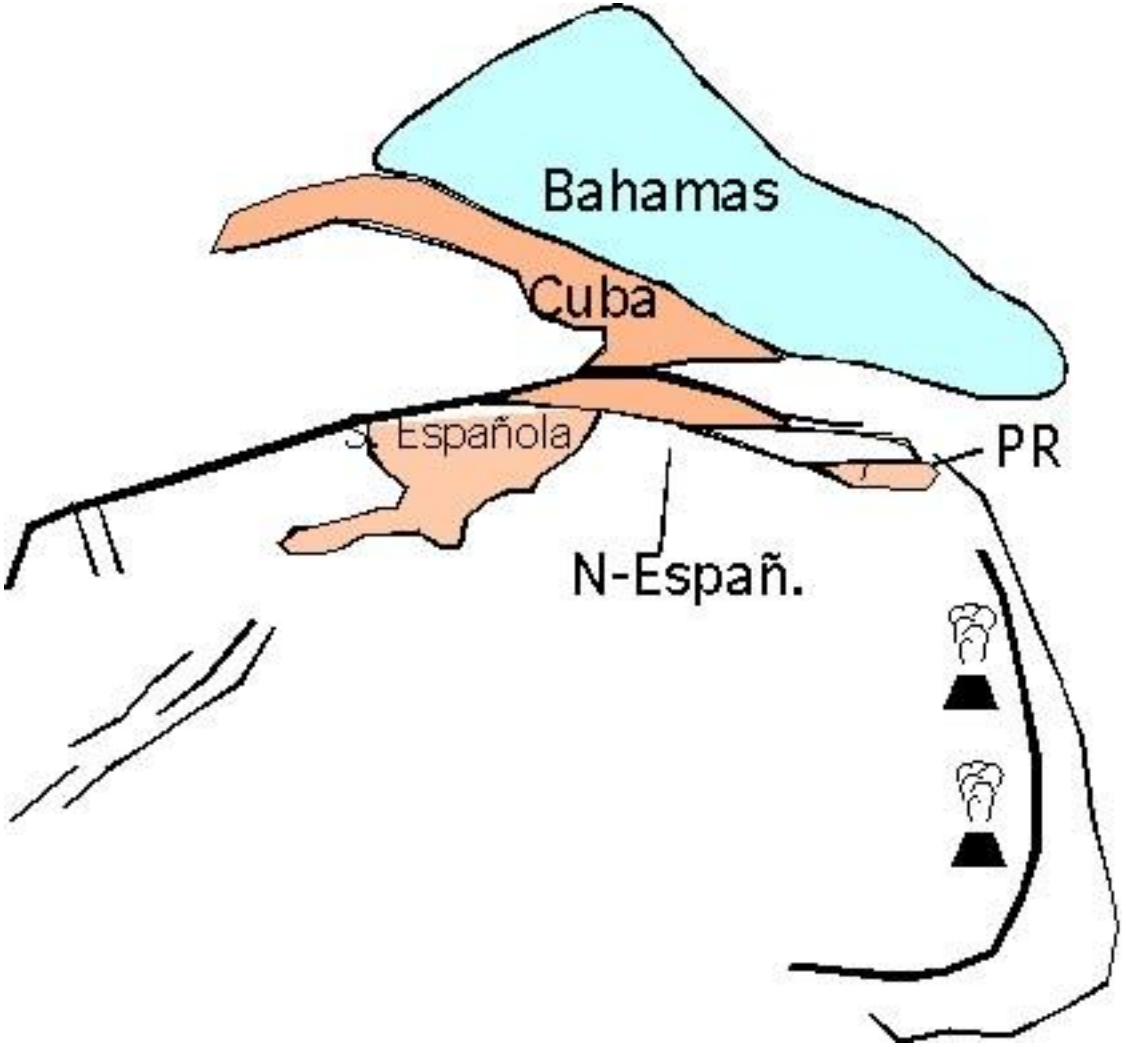
Based on Pindel, 1993

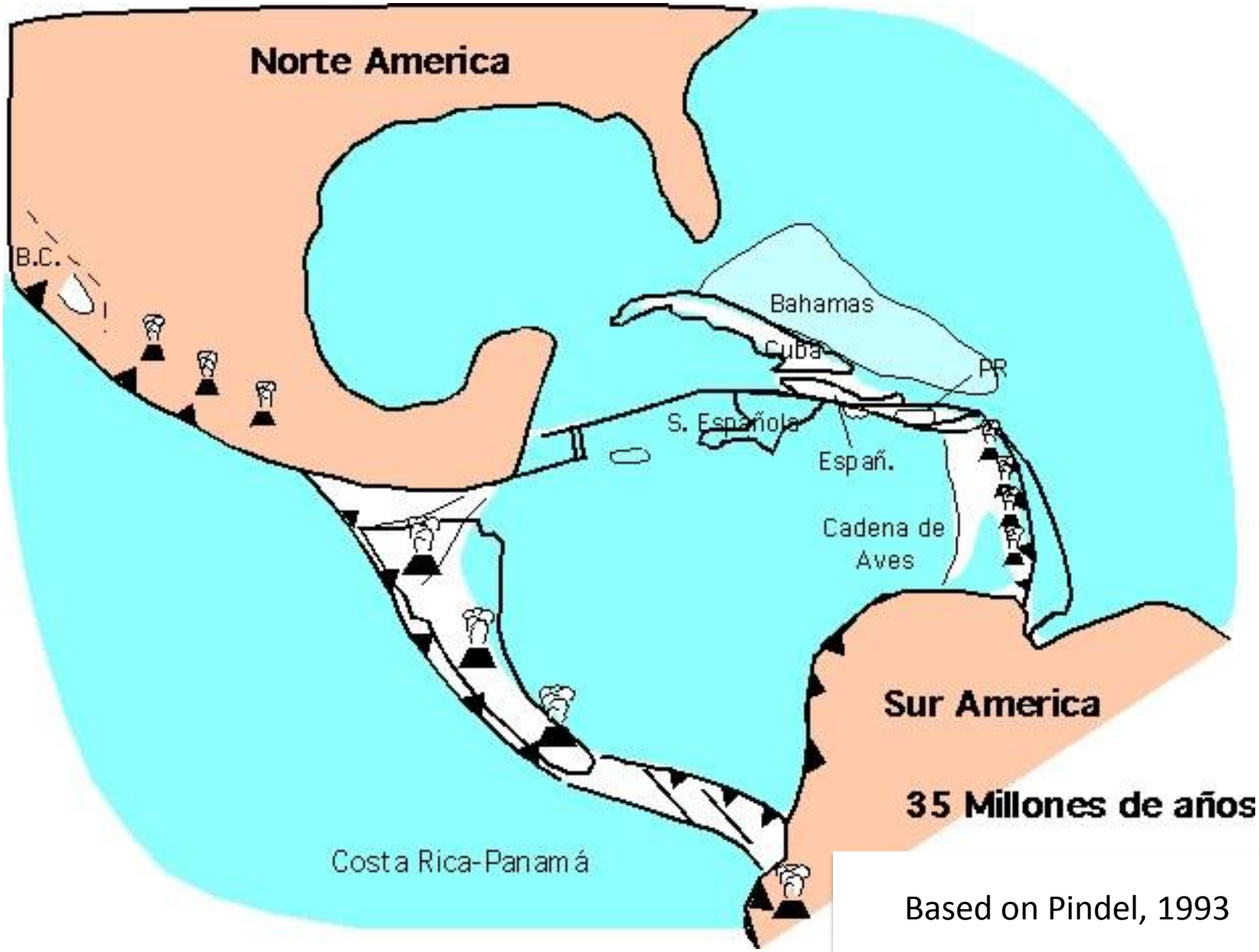

Norte America
Bahamas
B.C.
Cuba
N-Espan.
S. Española
PR
Cadena de
Aves
Sur America
Costa Rica-Panamá
59 Millones de años
Based on Pindel, 1993

Based on Pindel, 1993



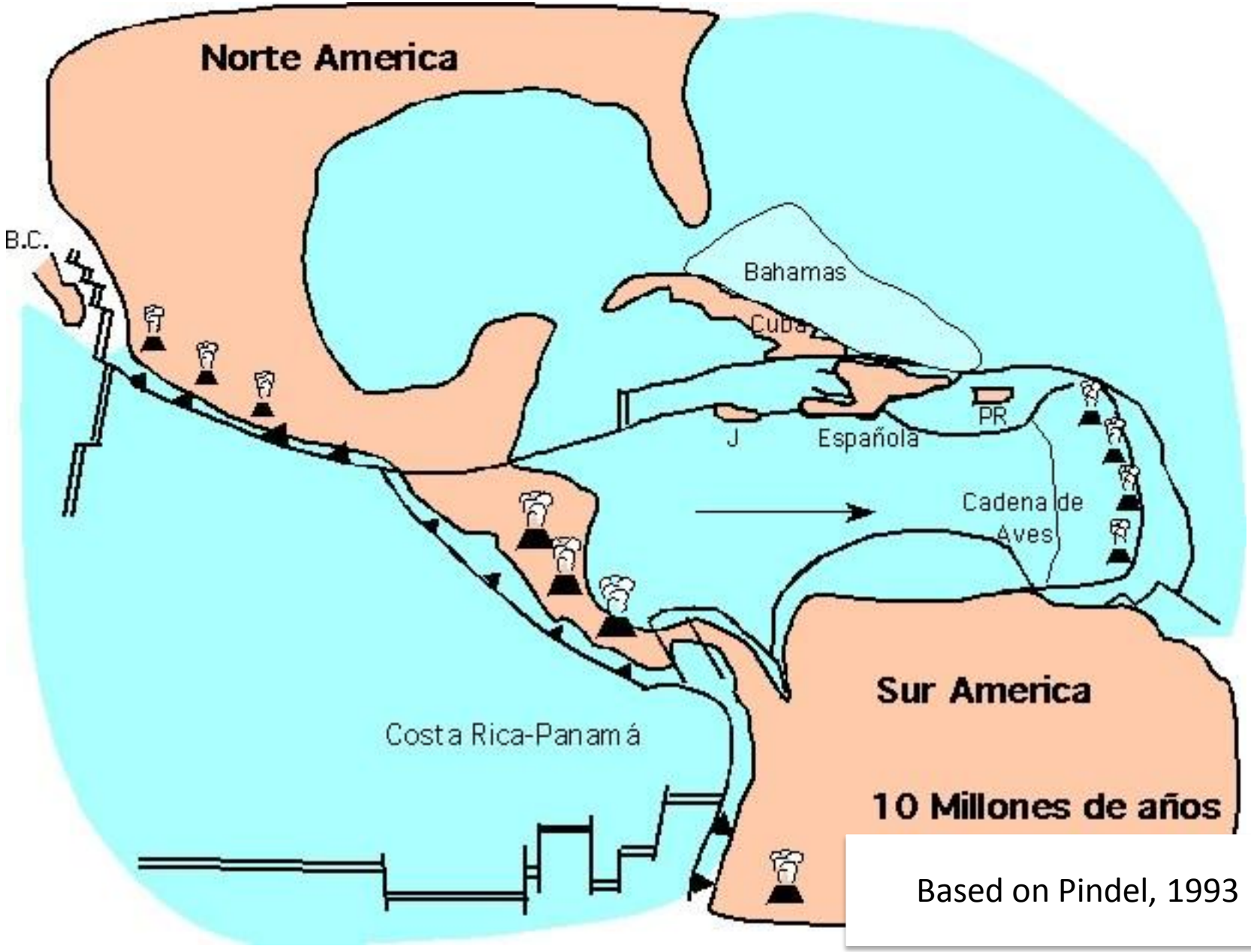
Based on Pindel, 1993


Bahamas
Cuba
Española
PR
N-Españ.



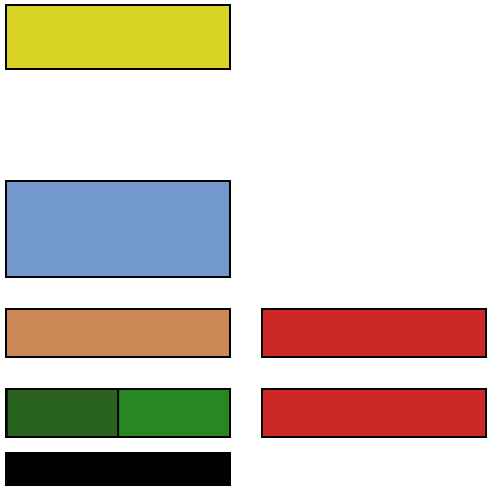
Based on Pindel, 1993

Based on Pindel, 1993

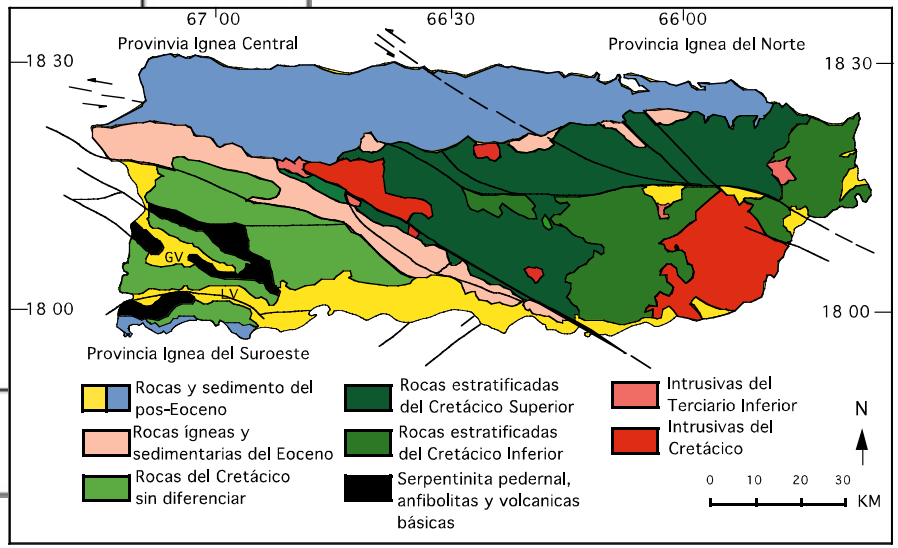


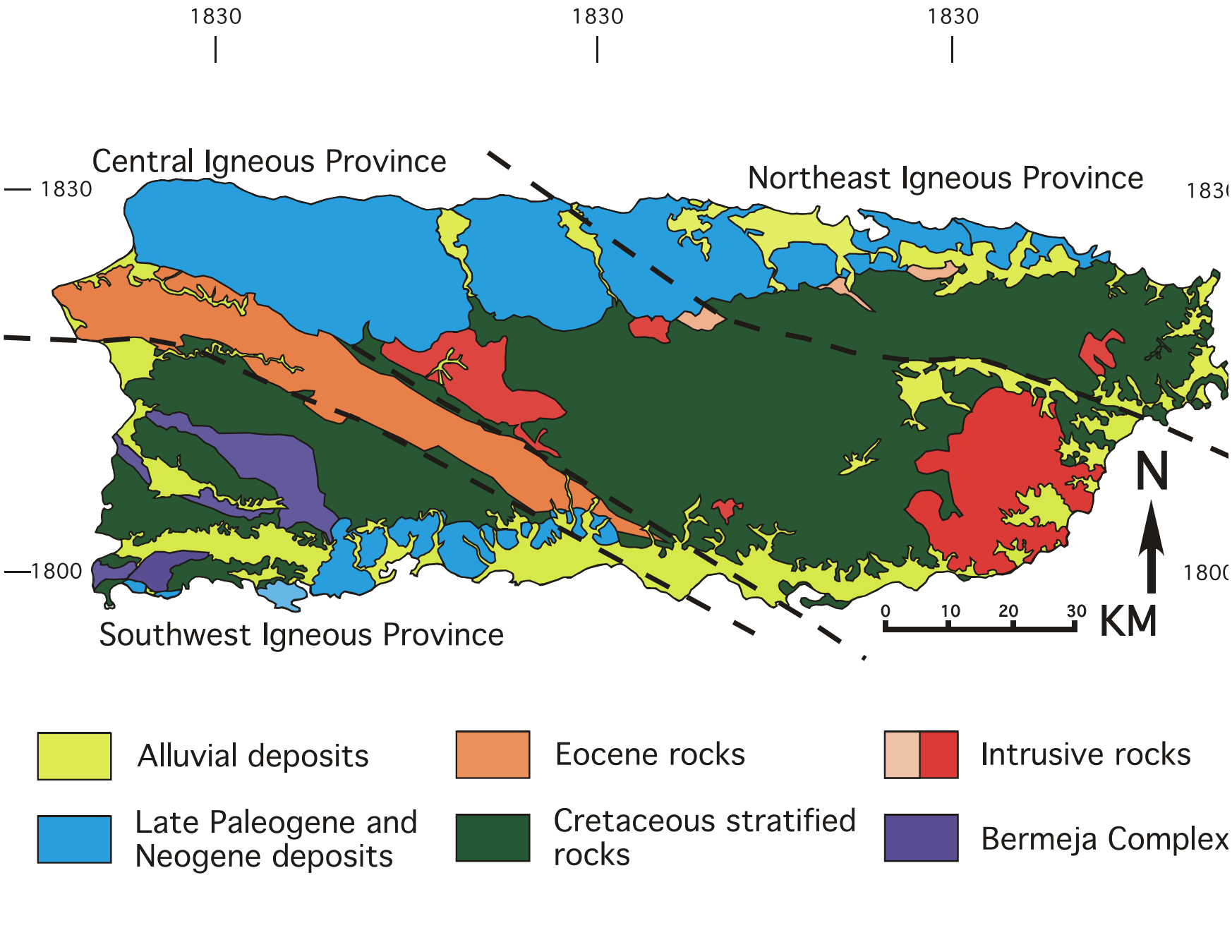
Based on Pindel, 1993

Era	period	Epoch	Age
Cenozoic	Quaternary	Holocene	0.01
		Pleistocene	1.6
	Neogene	Pliocene	5
		Miocene	23
	Paleogene	Oligocene	35
		Eocene	56
		Paleocene	65
Mesozoic	Cretaceous		145
	Jurassic		210
	Triassic		245
Paleozoic	Permian		
	Carboniferous		
	Devonian		
	Silurian		
	Ordovician		
	Cambrian		
	Proterozoic		
	Archean		

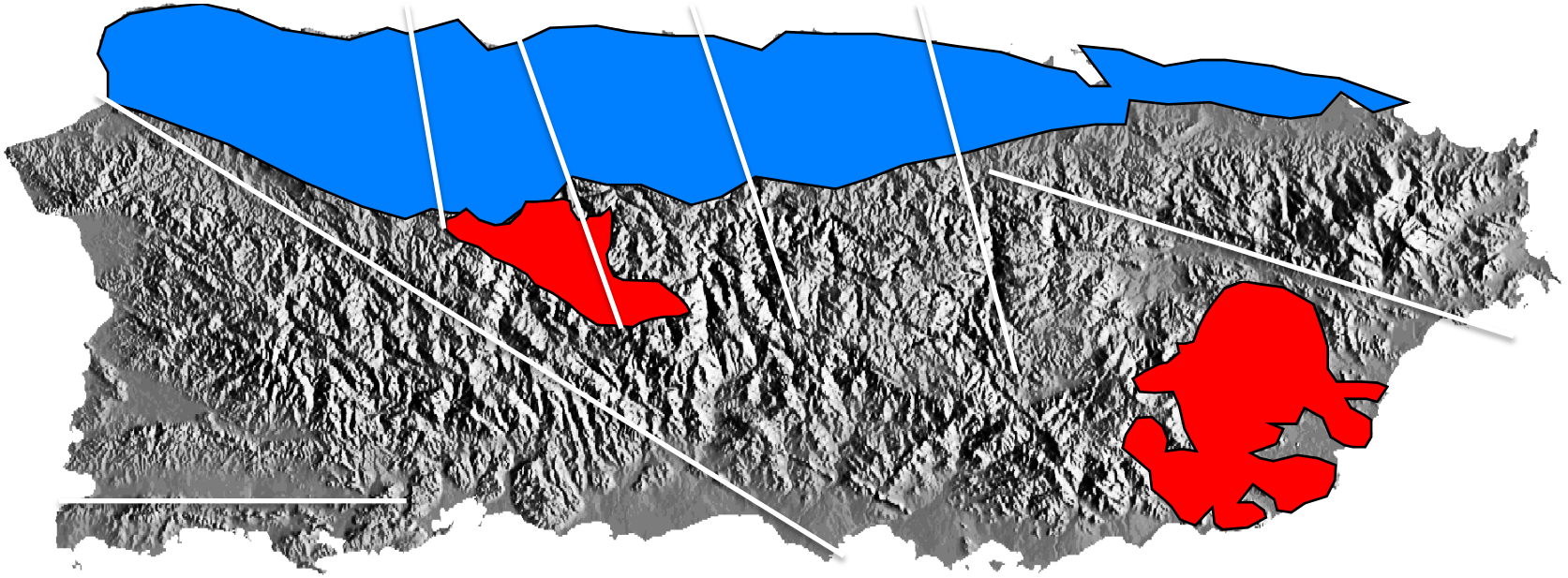


190 my



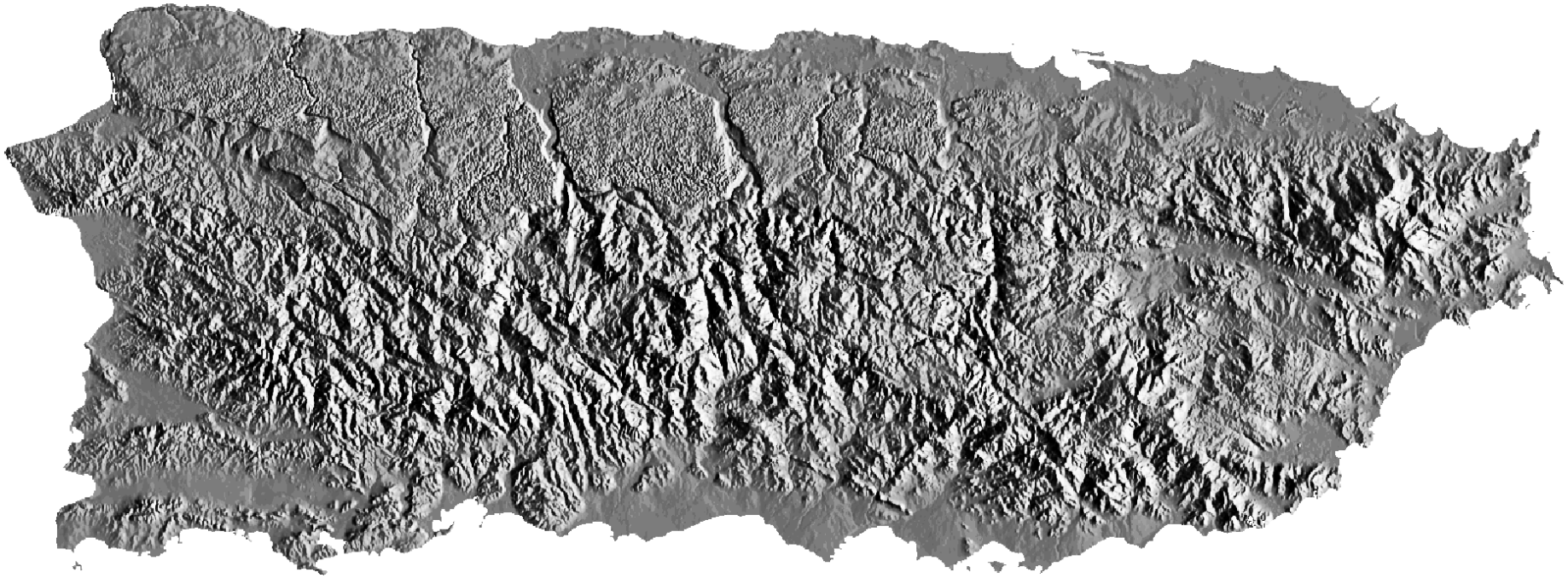

1830
1830
1830
Central Igneous Province
Northeast Igneous Province
1830
1800
Southwest Igneous Province
N
0
10
20
30
KM
Alluvial deposits
Eocene rocks
Intrusive rocks
Late Paleogene and Neogene deposits
Cretaceous stratified rocks
Bermeja Complex

Puerto Rico Digital Elevation Map, USGS

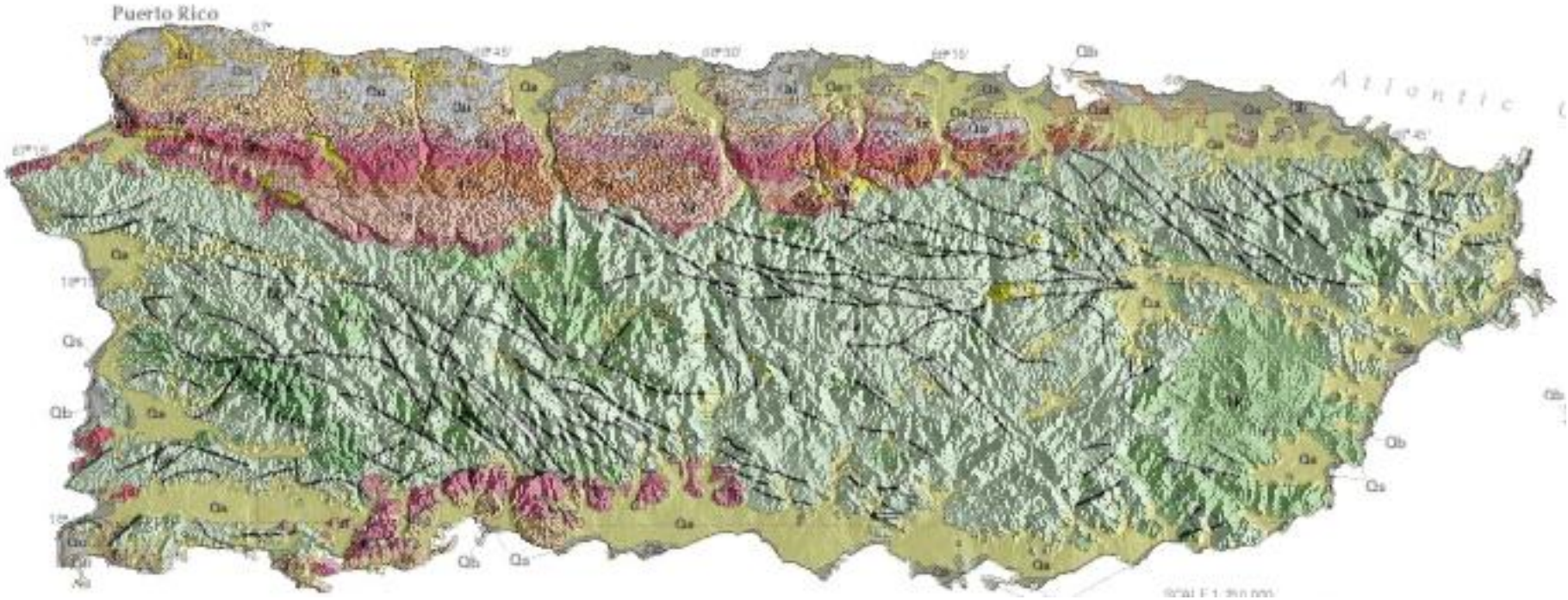


We can see:
- Igneous rocks bodies
- Karst topography
- Faults
-Valleys

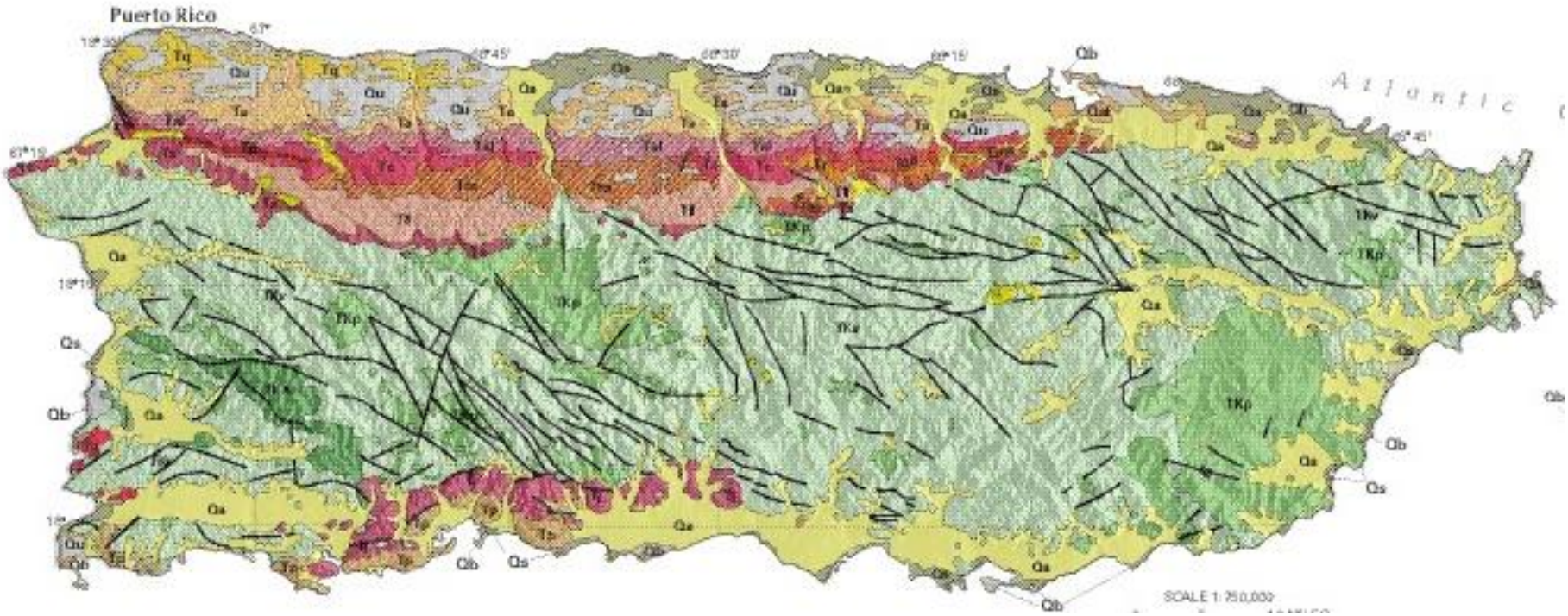
Digital Elevation Map D.E.M.

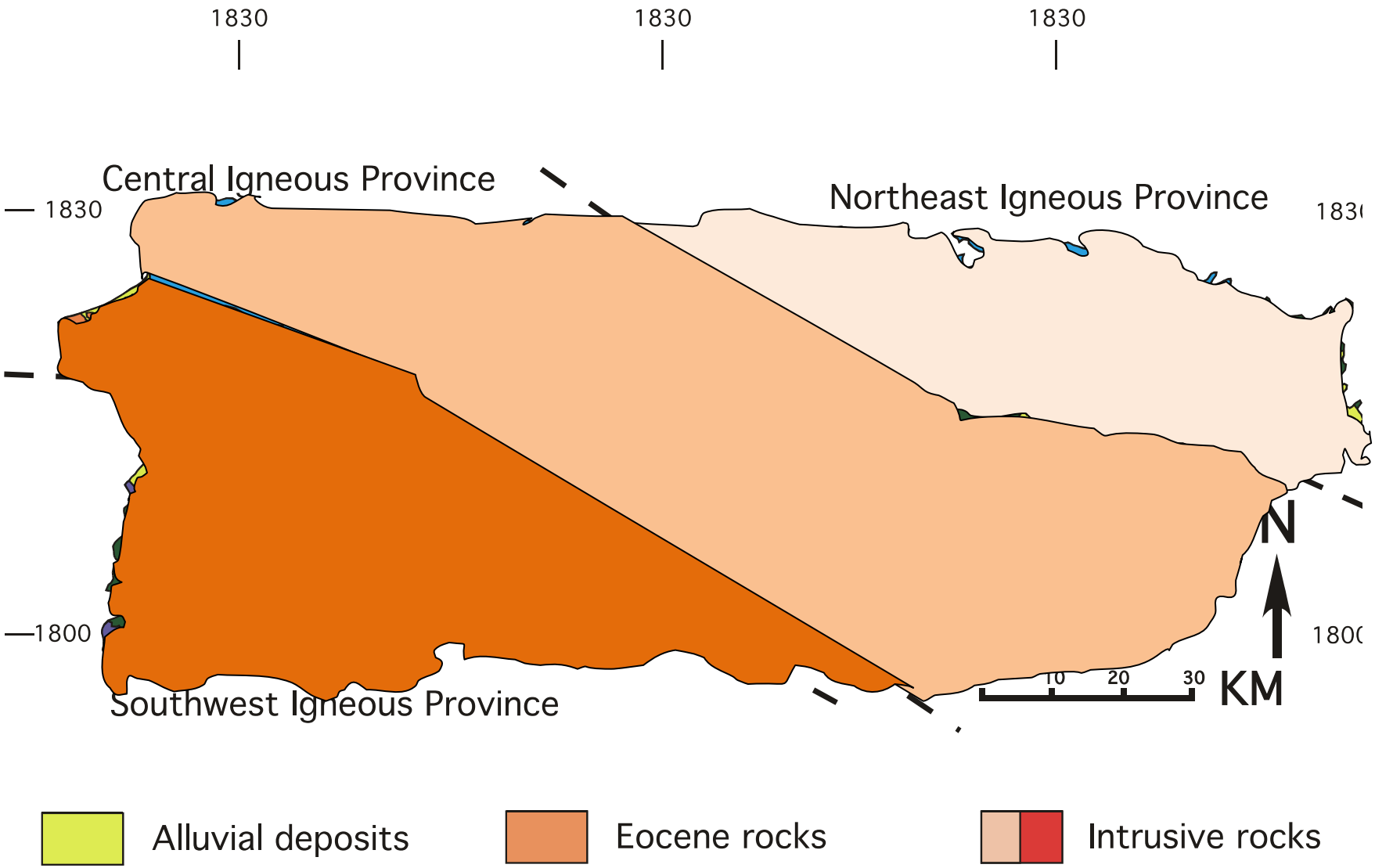



Puerto Rico

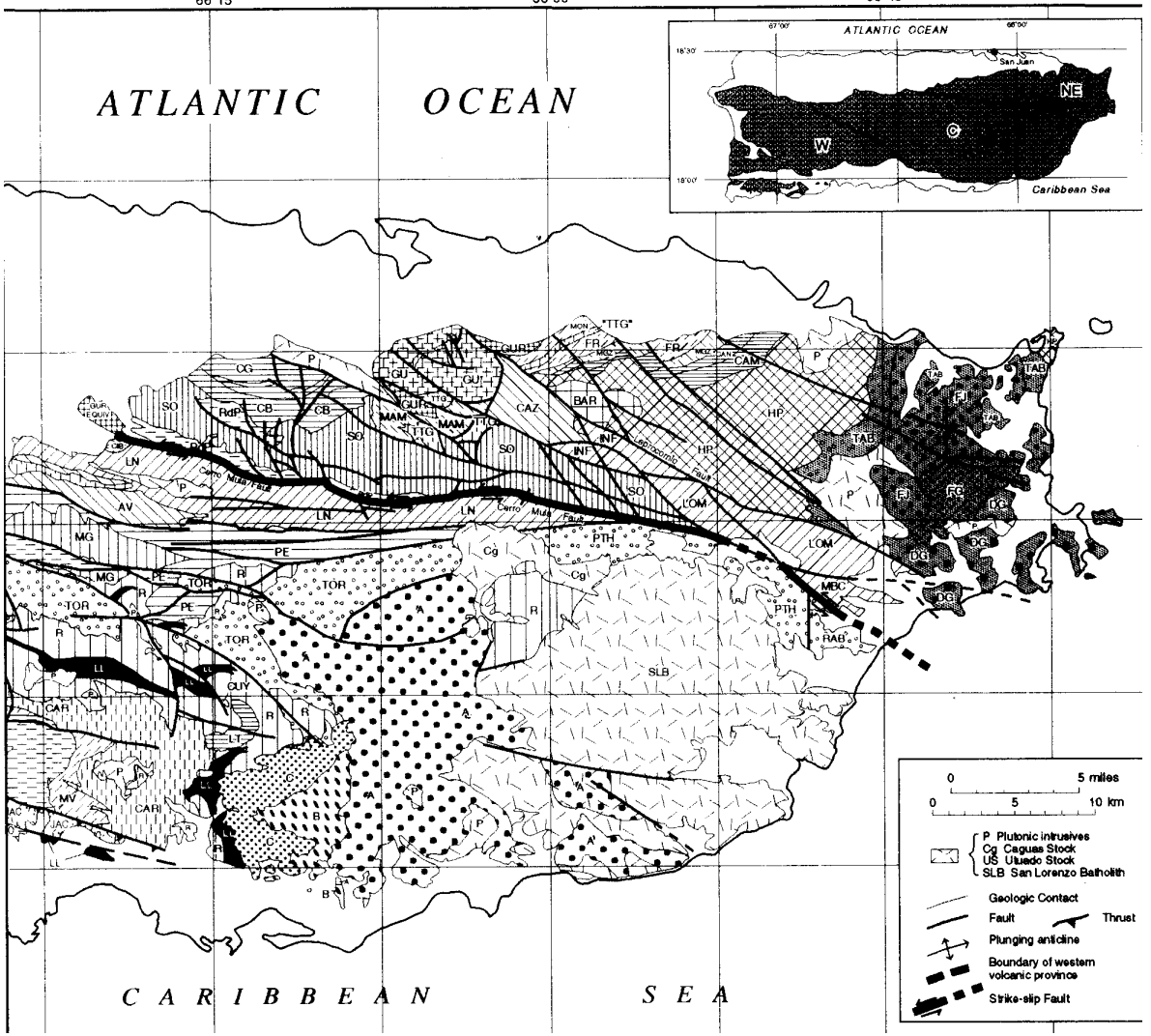

Puerto Rico
Atlantic

Combined geologic and Digital maps of Puerto Rico.

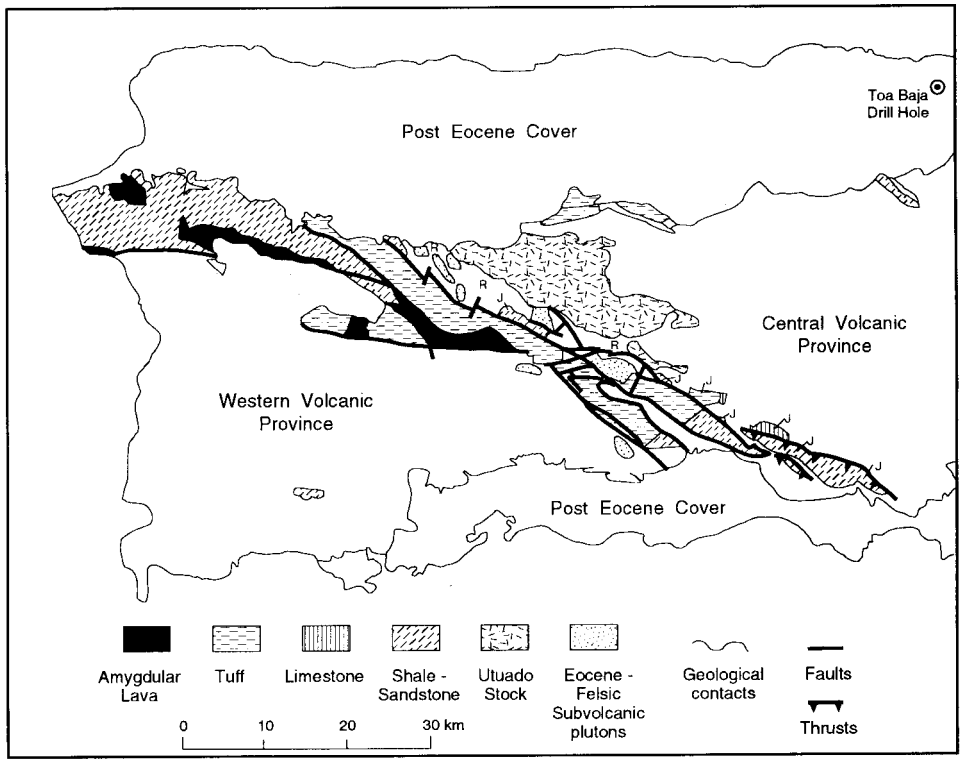



1830
1830
1830
Central Igneous Province
Northeast Igneous Province
1830
1800
1800
Southwest Igneous Province
N
10
20
30
KM
Alluvial deposits
Eocene rocks
Intrusive rocks
Late Paleogene and Neogene deposits
Cretaceous stratified rocks
Bermeja Complex

The Northeast Igneous Province is separated from the Central Igneous Province by the **Cerro de Mula Fault**.



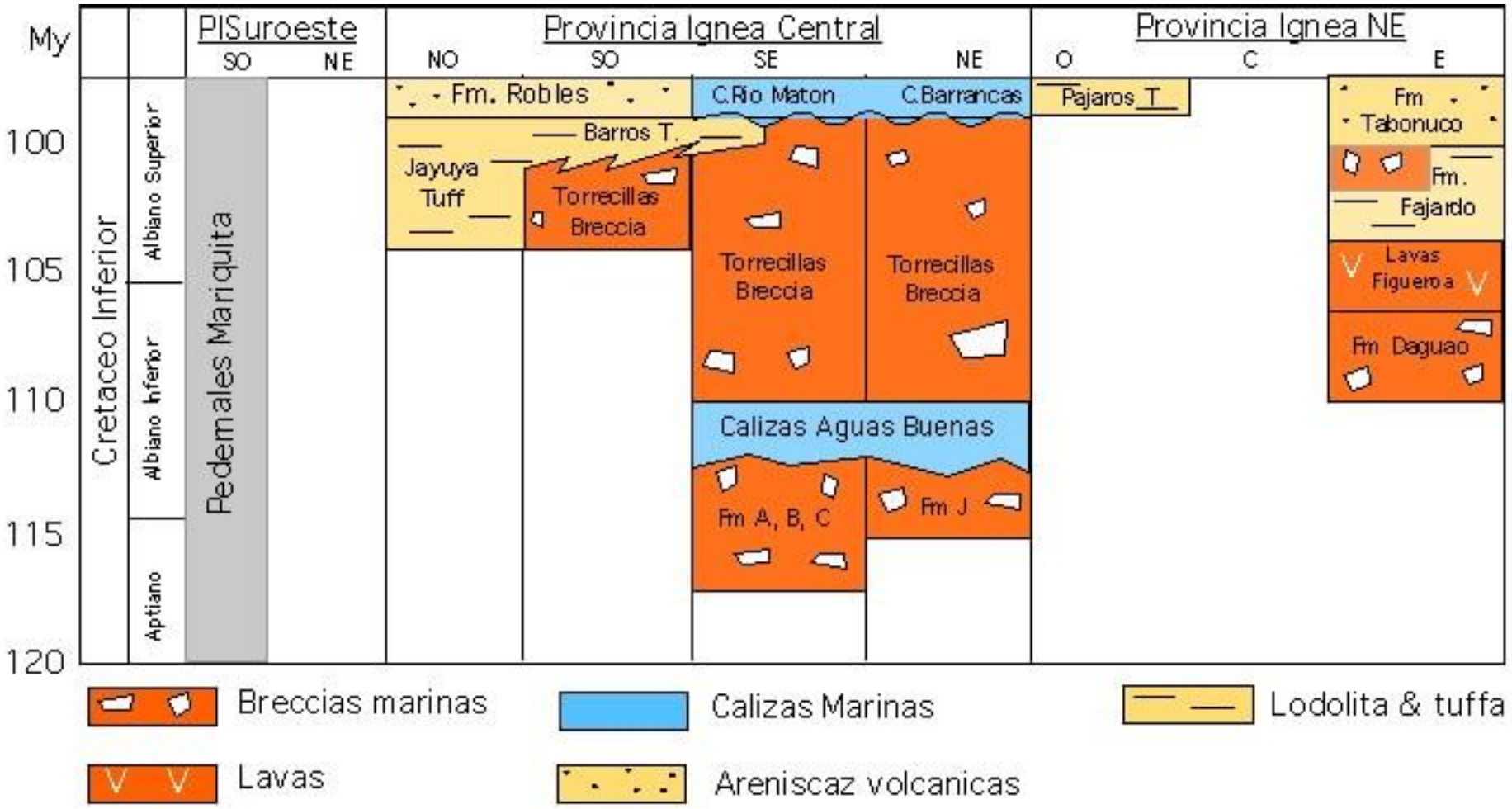
This fault extends for at least 50 Km without any matching between rocks at both sides. Deformation of the rocks along the faults suggest a left-lateral movement.

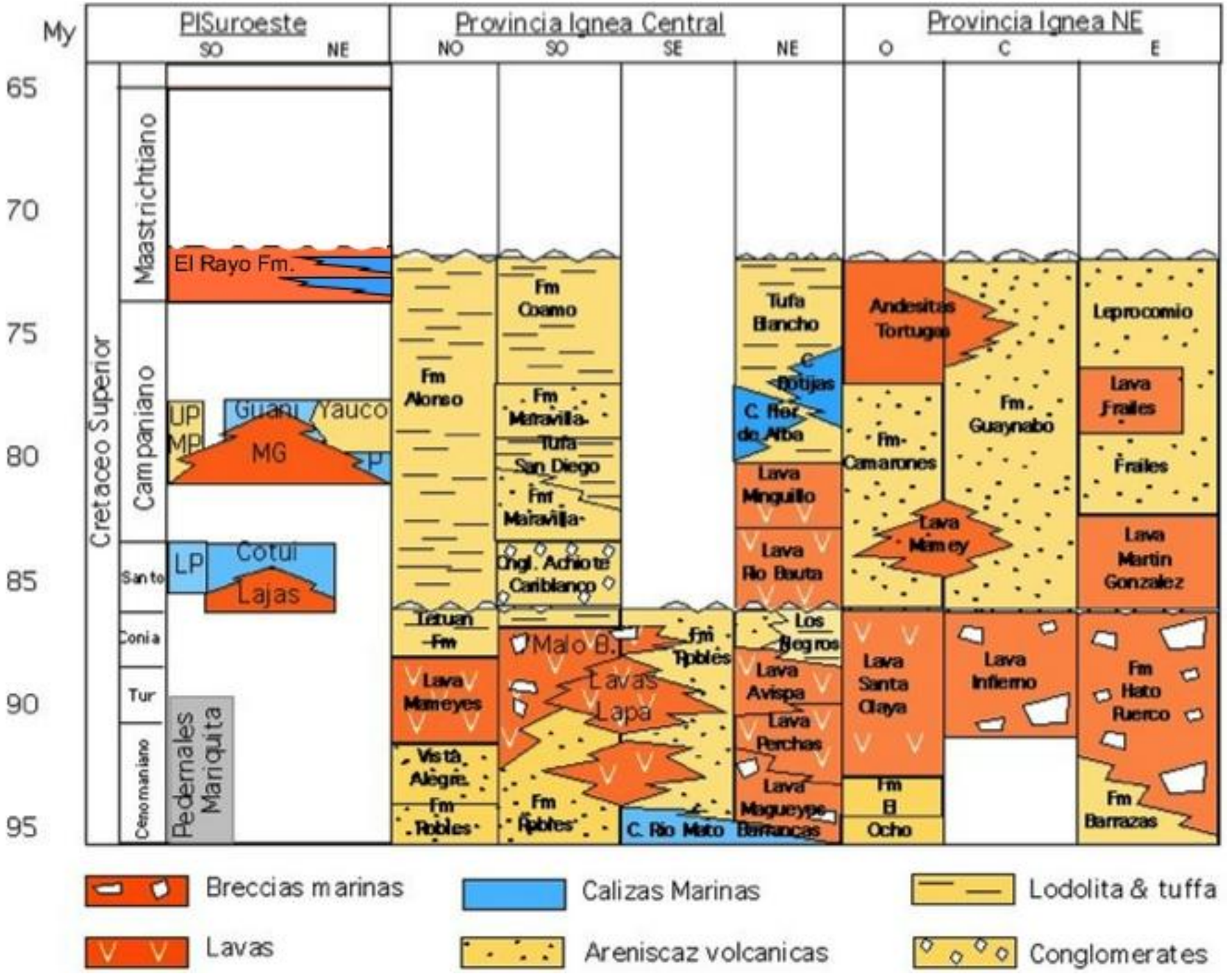


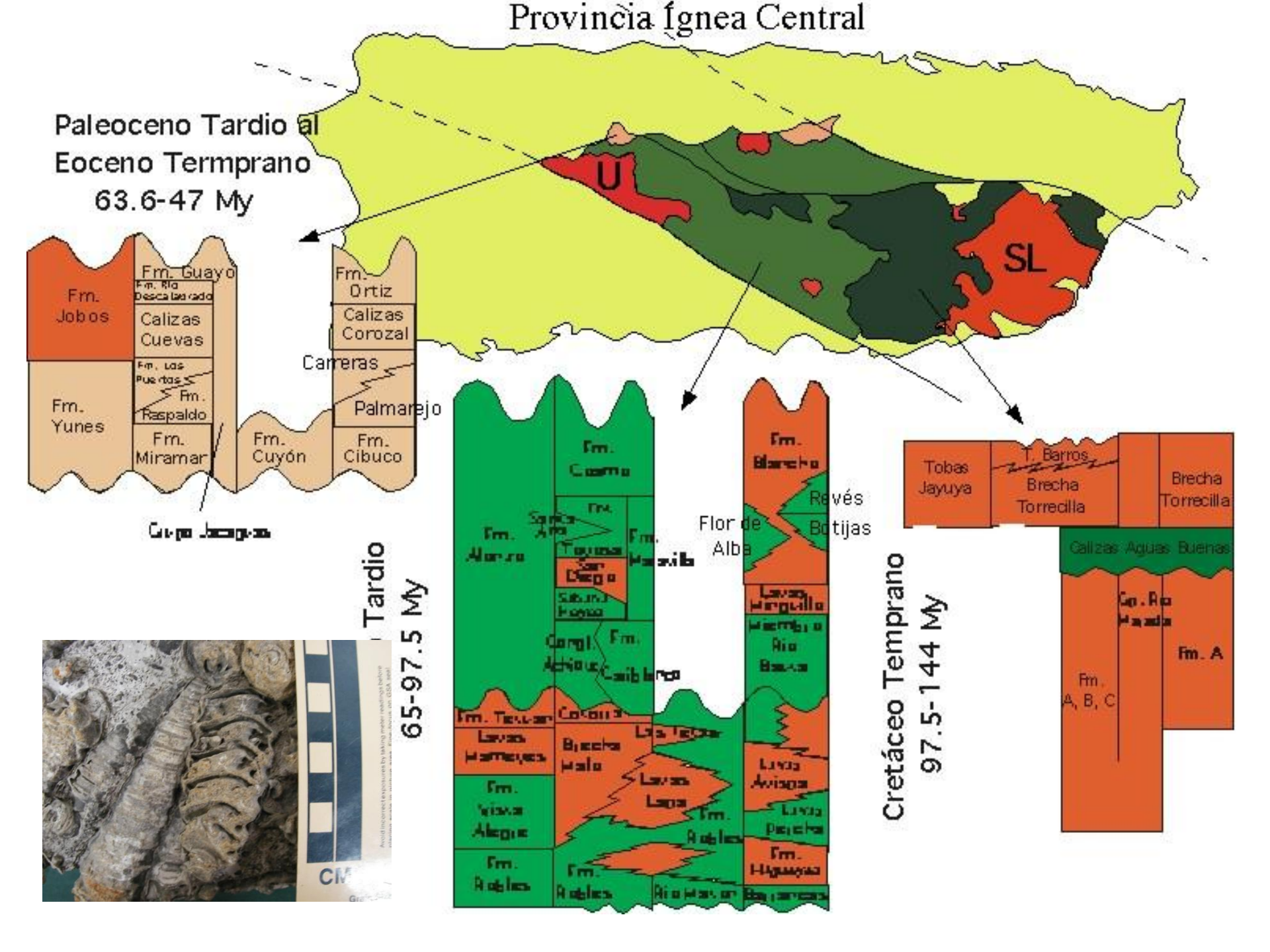
The Central Igneous Province and the Southwestern Igneous Province are separated by the Southern Puerto Rico Fault Zone.

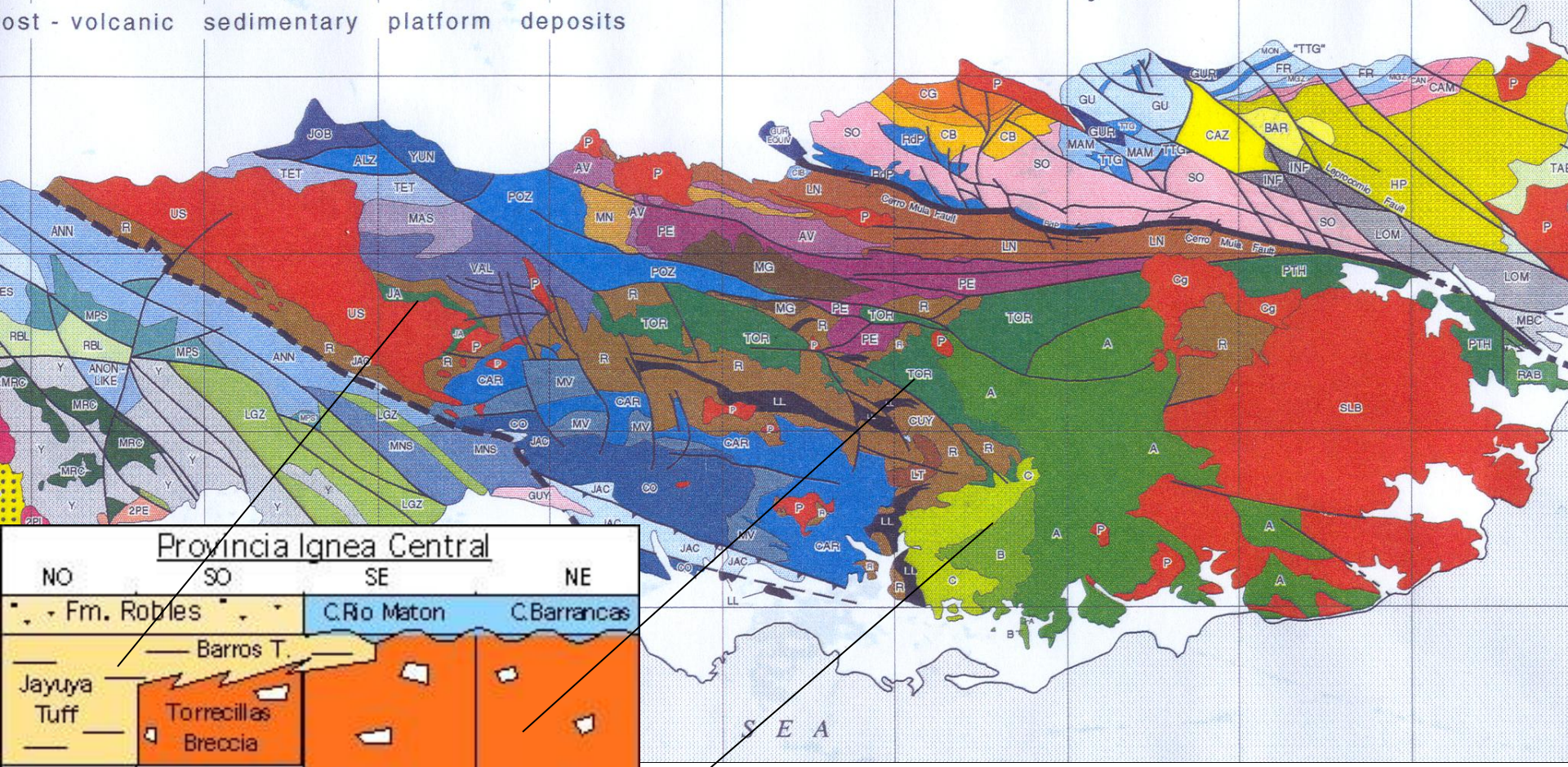
Rocks within the fault zone are submarine volcanic and submarine fan deposited in a basin during the Eocene. The southwestern Province collided with central Puerto Rico during the Eocene resulting in deformation and uplift of the basin rocks.

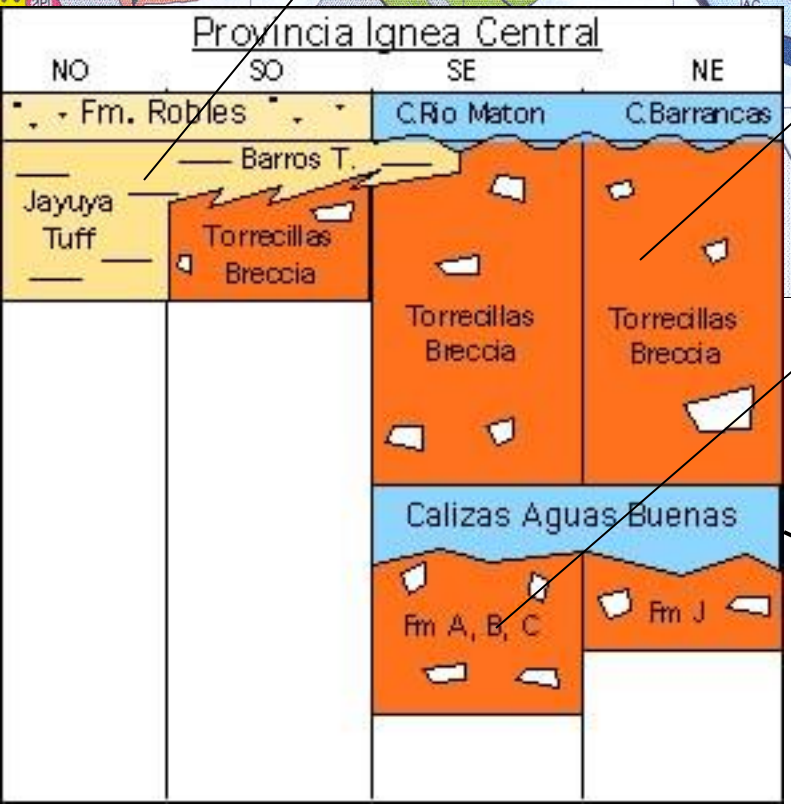
Stratigraphic correlation of Lower Cretaceous rocks of Puerto Rico.




My
PISuroeste
SO
NE
Provincia Ignea Central
NO
SO
SE
NE
Provincia Ignea NE
O
C
E
65
70
75
80
85
90
95
Cretaceo Superior
Maastrichtiano
Campaniano
Santo
Coniac
Tur
Cenomaniano
El Rayo Fm.
UP
MP
MG
LP
Guanl
Yauco
P
Cotui
Lajas
Pedernales
Mariquita
Fm Alonso
Fm Cosmo
Fm Maravilla
Tufa San Diego
Fm Maravilla
Cngl. Achiote
Caribbean
Tetuan Fm
Lava Mameyes
Vista Alegre
Fm Robles
Malo B.
Lavas Lapa
Fm Robles
C. Rio Mato
Tufa Blanco
C. Botijas
C. Rio de Alba
Lava Minguito
Lava Rio Bauta
Los Negros
Lava Avispa
Lava Perchas
Lava Magueyes
Barracas
Andesitas Tortuga
Fm. Camarones
Fm. Guaynabo
Lava Mamey
Lava Santa Olaya
Fm El Ocho
Lava Infierno
Leprocomio
Lava Frailes
Frailes
Lava Martin Gonzalez
Fm Hato Puerco
Fm Barrazas
Breccias marinas
Lavas
Calizas Marinas
Areniscaz volcanicas
Lodolita & tuffa
Conglomerates


Provincia Ígnea Central
Paleoceno Tardio al
Eoceno Termprano
63.6-47 My
U
SL
Fm. Jobos
Fm. Guayo
Fm. Río Descalabrado
Calizas Cuevas
Fm. Las Puertas
Fm. Raspaldo
Fm. Miramar
Fm. Yunes
Fm. Cuyón
Fm. Ortiz
Calizas Corozal
Carreras
Palmarejo
Fm. Cibuco
Tardio
65-97.5 My
Fm. Cuamo
Fm. Alberro
Fm. Blanche
Revés
Botijas
Flor de Alba
Fm. Caribbean
Fm. Robles
Fm. Higuayos
Cretáceo Temprano
97.5-144 My
Tobas Jayuya
T. Barros
Brecha Torrecilla
Brecha Torrecilla
Calizas Aguas Buenas
Fm. A
Fm. A, B, C

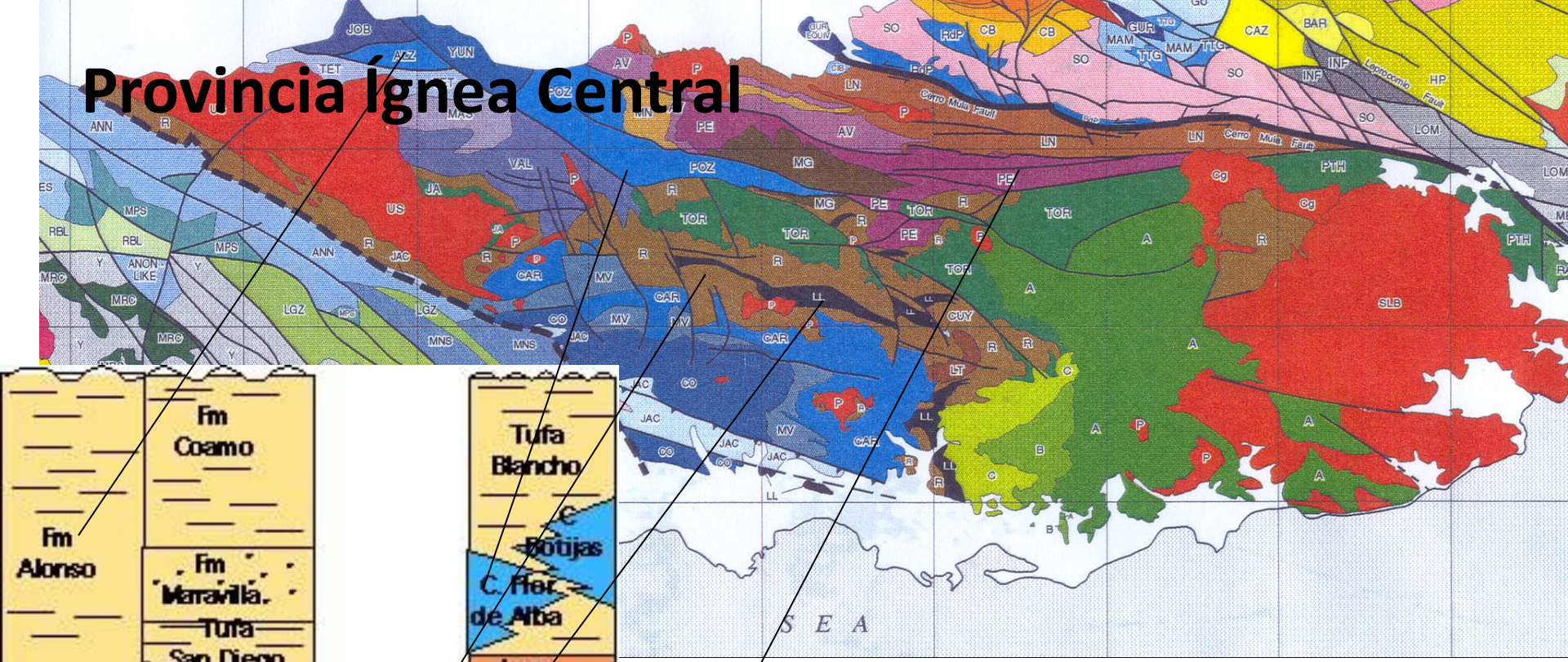




Stratigraphic correlations of the Lower Cretaceous rocks.

112 My

Provincia Ígnea Central

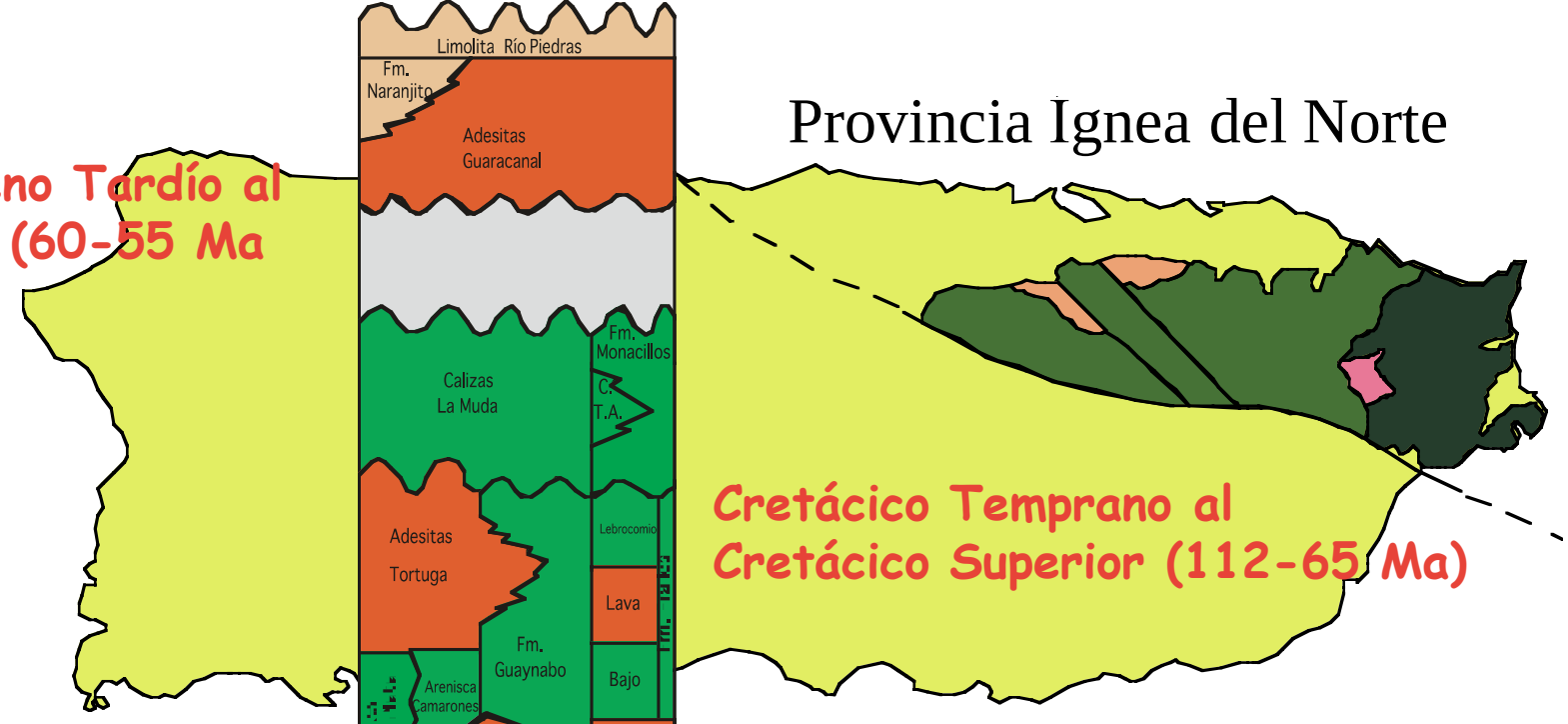


Stratigraphic correlations of the Lower Cretaceous rocks.

Lapa Lava Formation, Upper Cretaceous
Central Igneous Provinces

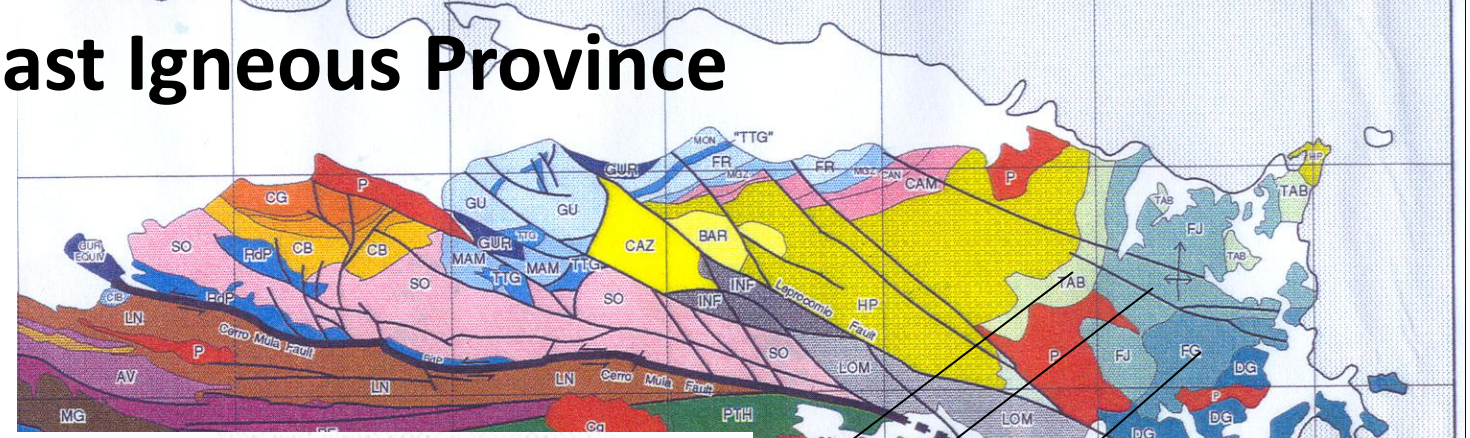
Provincia Ignea del Norte

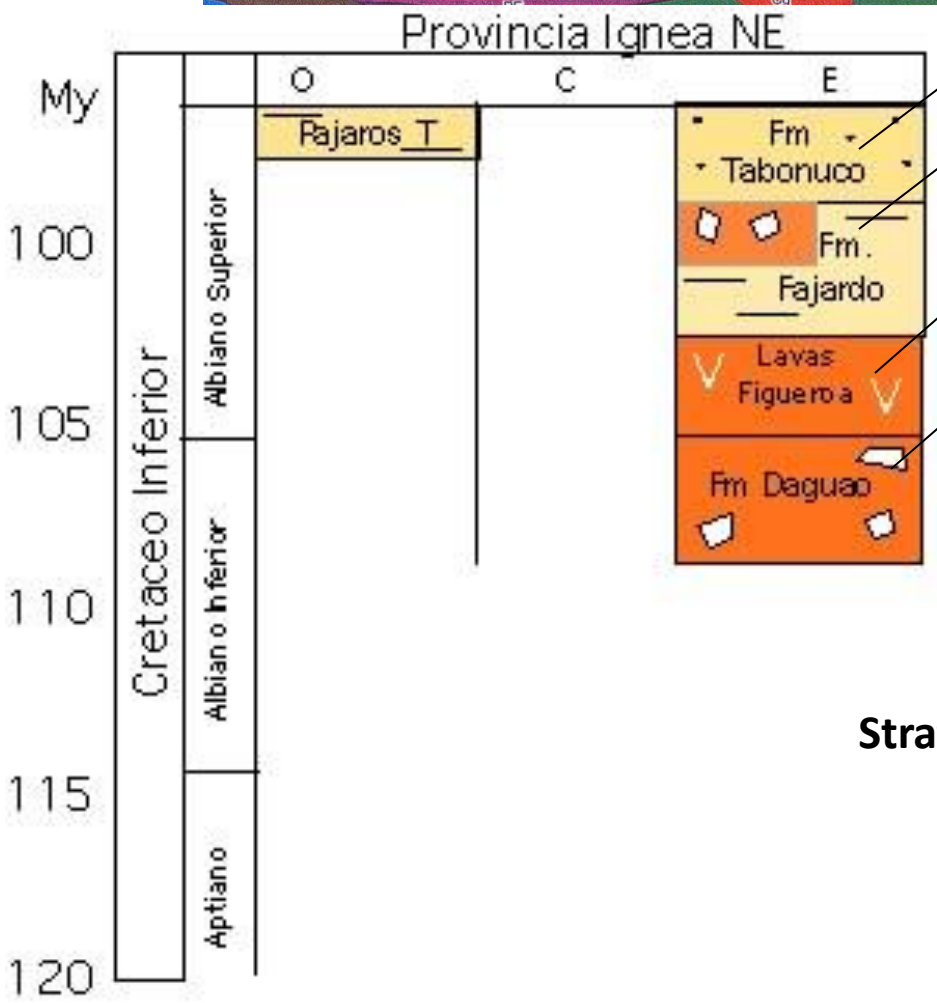
Paleoceno Tardío al Eoceno (60-55 Ma



Cretácico Temprano al Cretácico Superior (112-65 Ma)

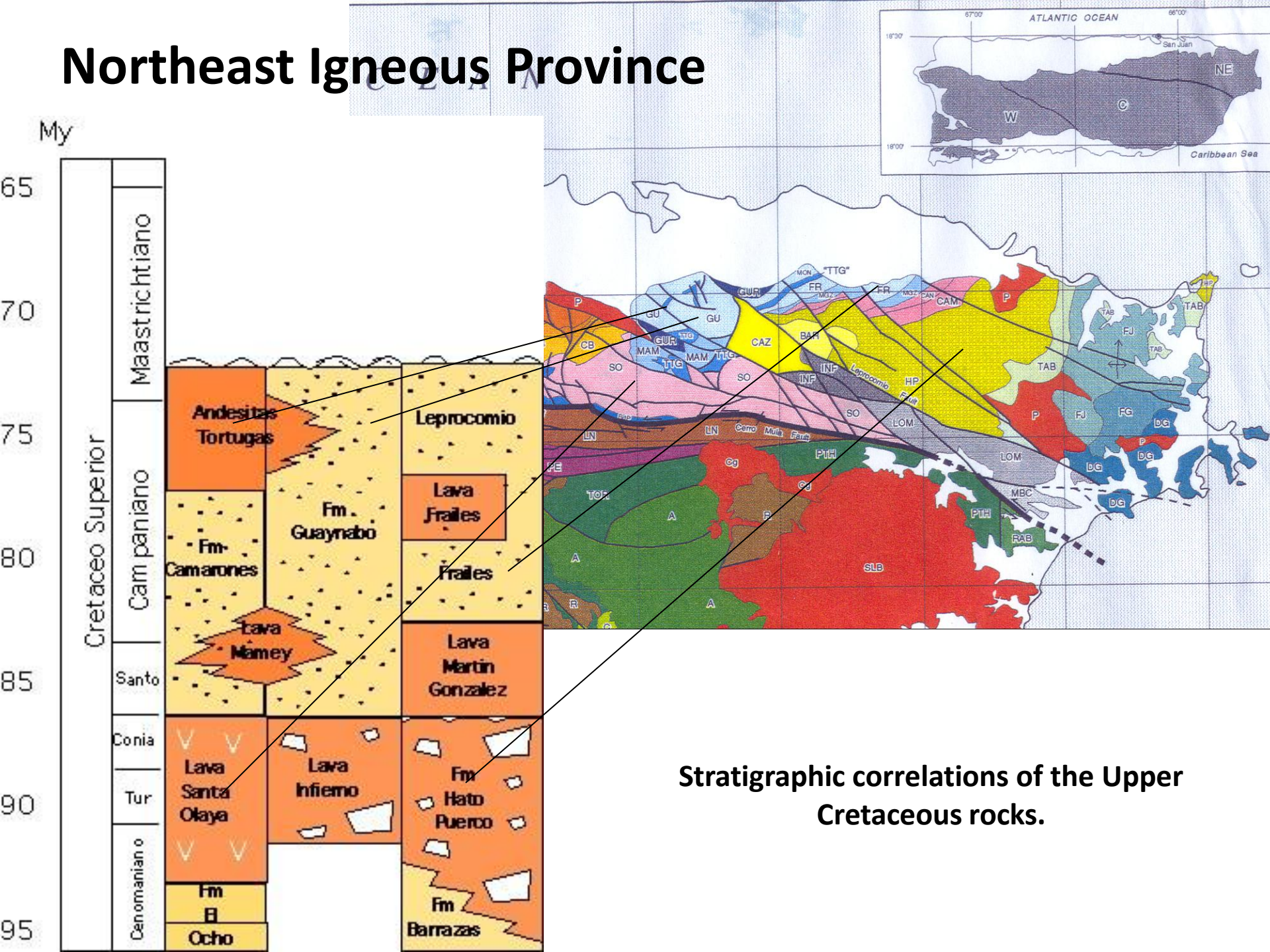
Northeast Igneous Province



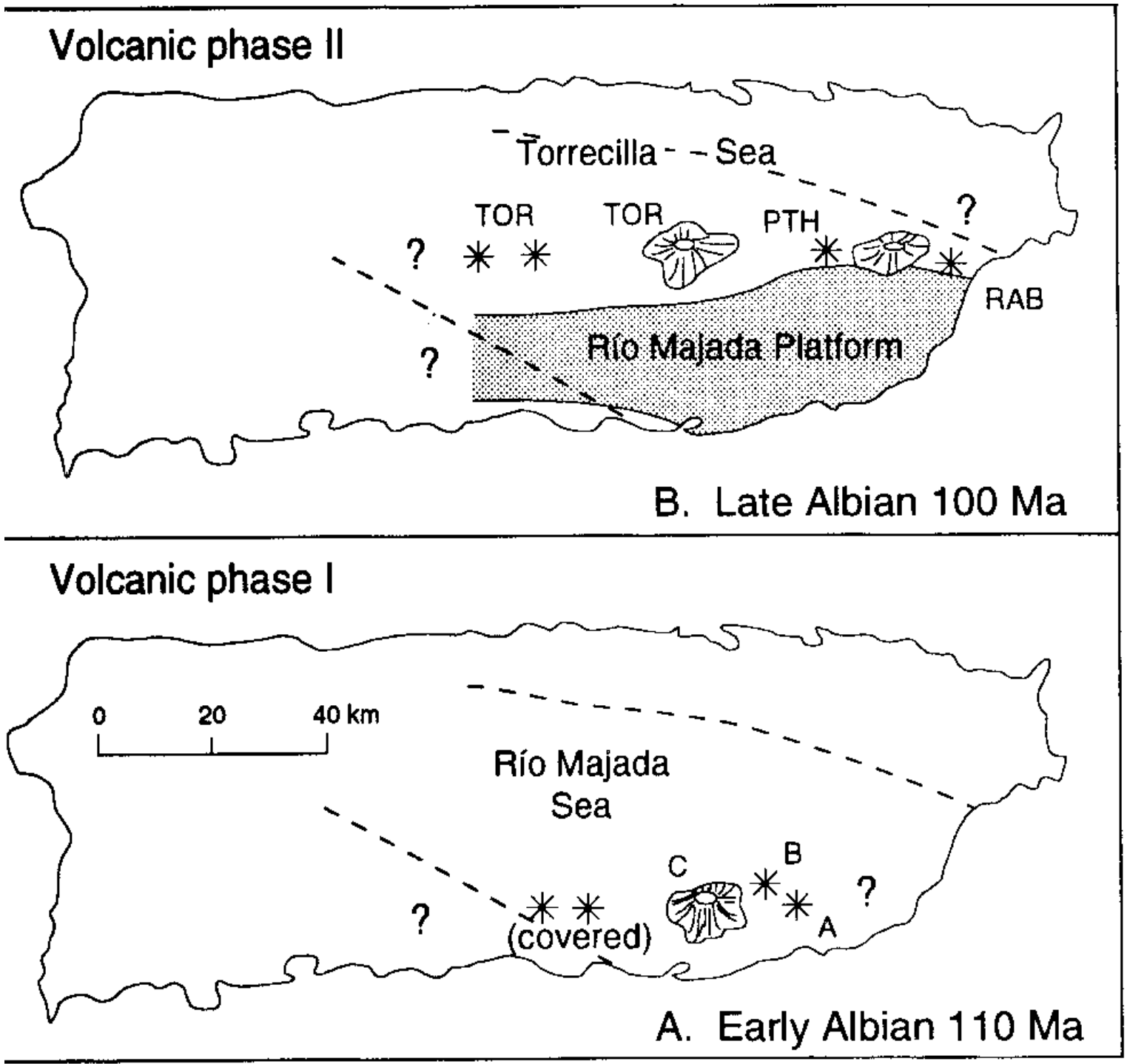


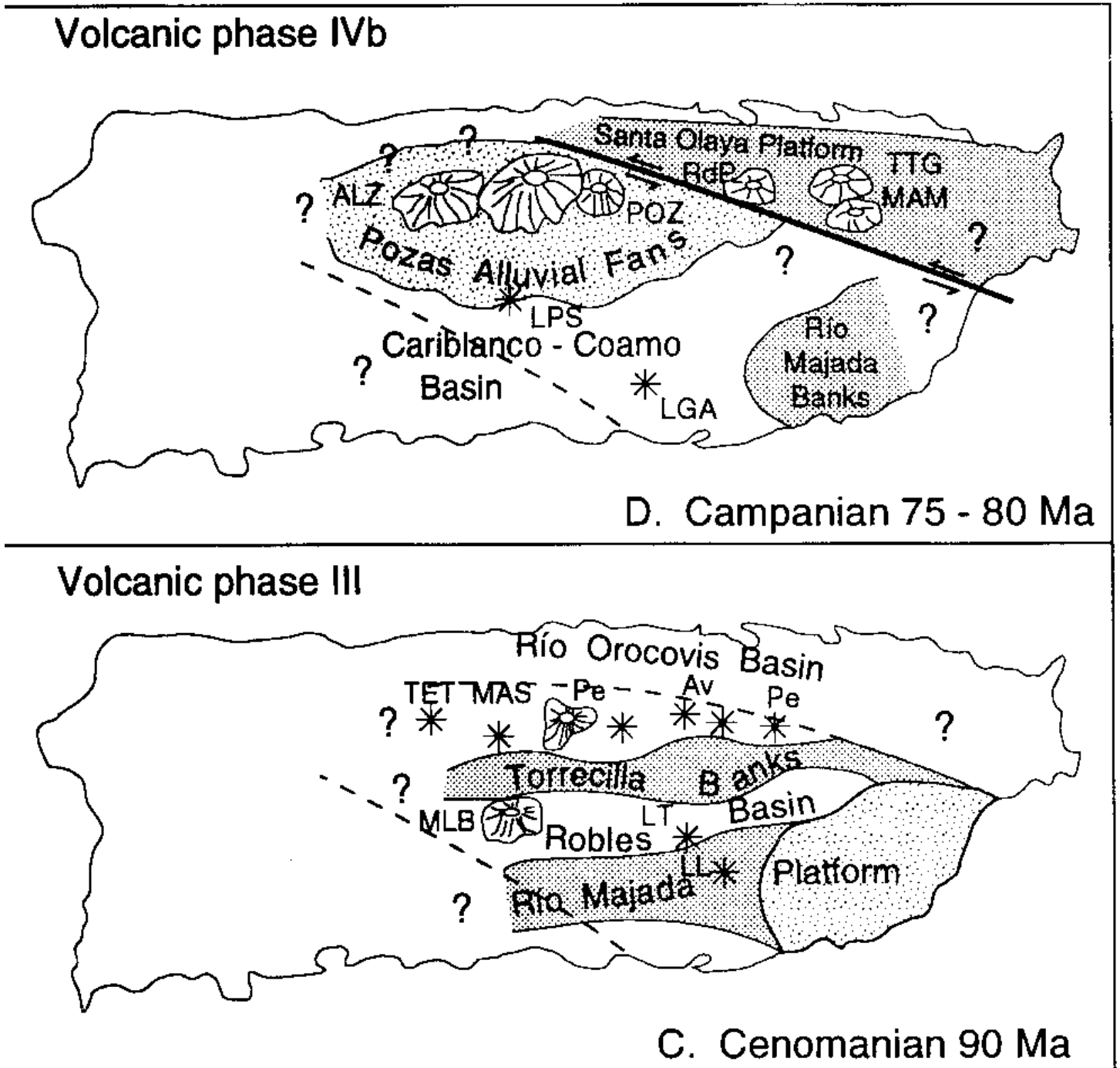
Stratigraphic correlations of the Lower Cretaceous rocks.

Northeast Igneous Province

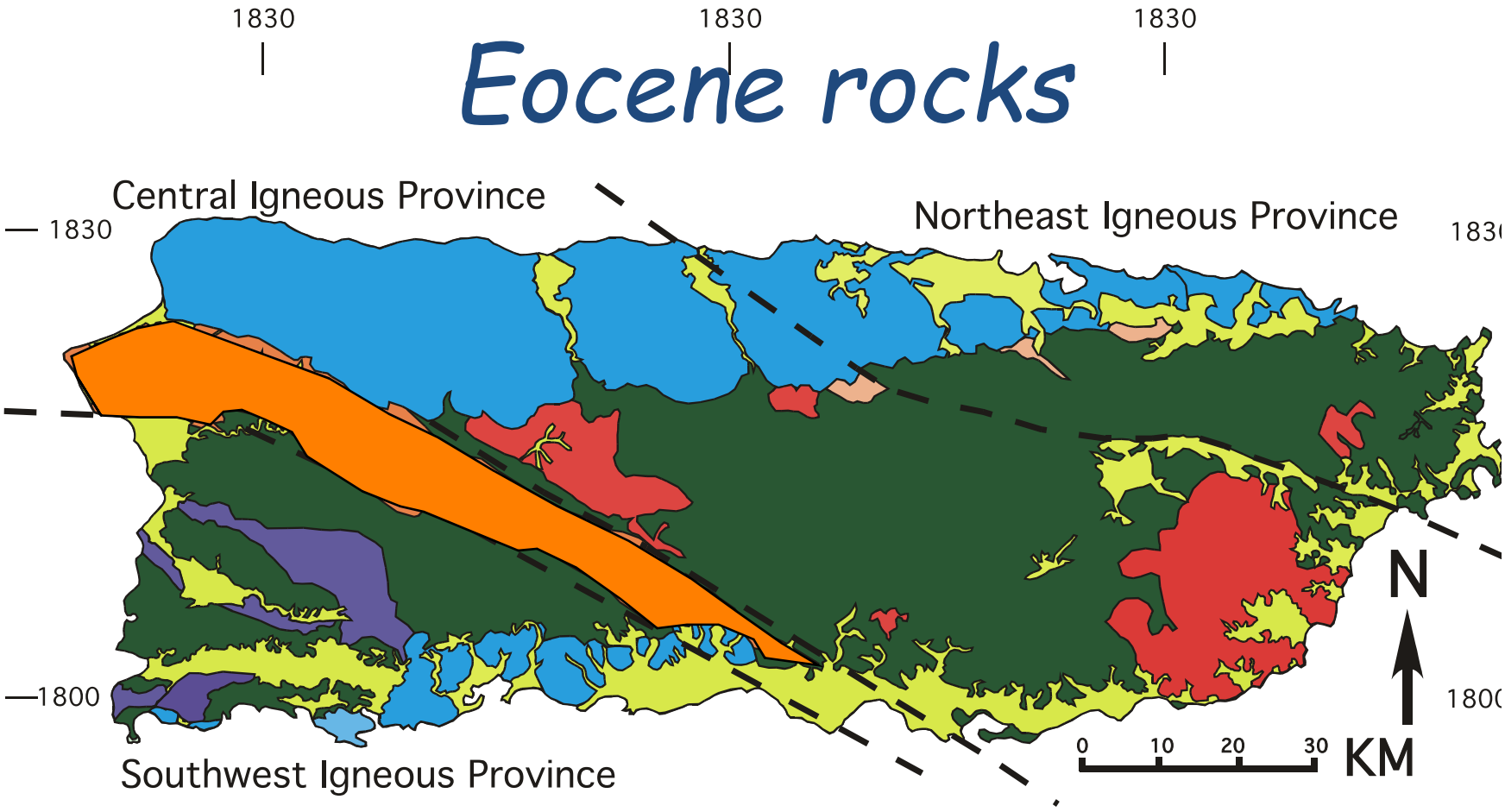


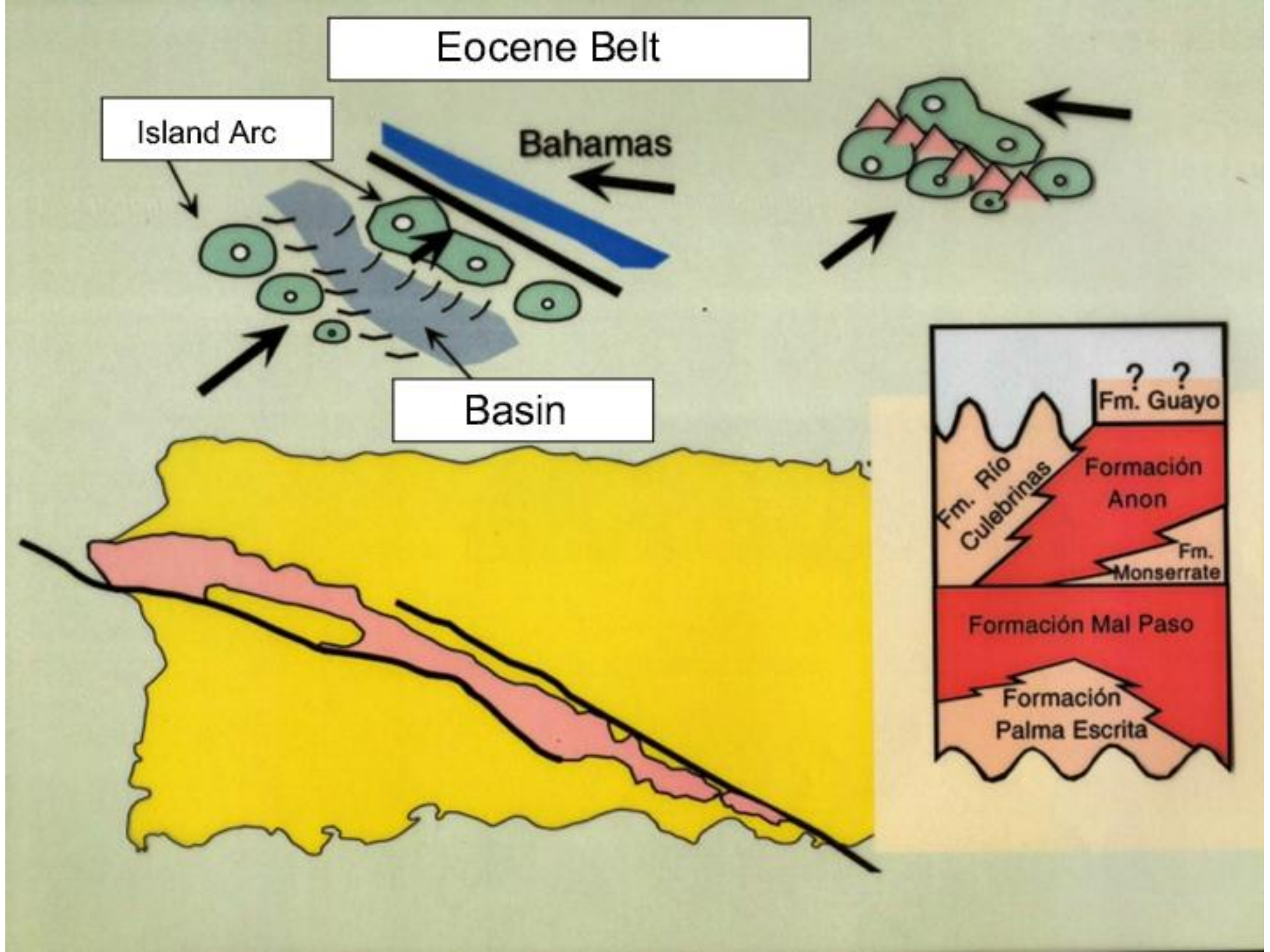
Stratigraphic correlations of the Upper Cretaceous rocks.


Volcanic phase II
Torrecilla Sea
TOR
TOR
PTH
?
?
?
RAB
Río Majada Platform
B. Late Albian 100 Ma
Volcanic phase I
0
20
40 km
Río Majada
Sea
C
B
A
?
?
(covered)
A. Early Albian 110 Ma

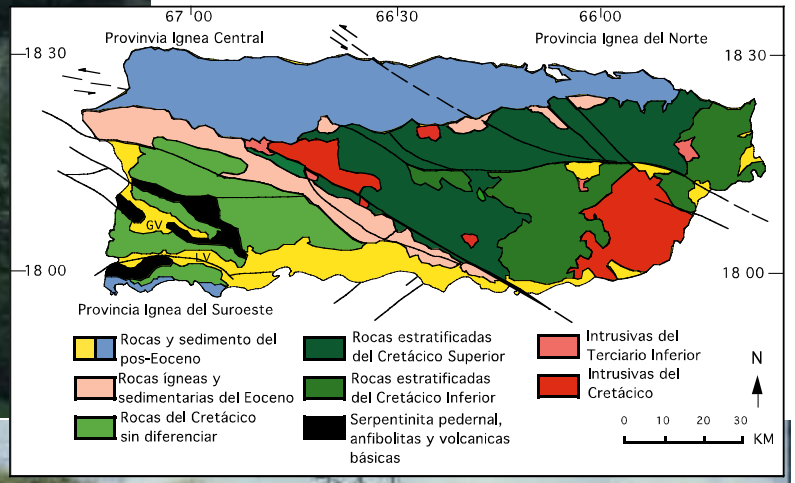

Volcanic phase IVb
Santa Olaya Platform
RdP
TTG
MAM
ALZ
POZ
Pozas Alluvial Fans
LPS
Cariblanco - Coamo
Basin
LGA
Río
Majada
Banks
D. Campanian 75 - 80 Ma
Volcanic phase III
Río Orocovis Basin
TET
MAS
Pe
Av
Pe
Torrecilla
Banks
MLB
LT
Basin
Robles
LL
Platform
Río Majada
C. Cenomanian 90 Ma

Eocene rocks




Eocene Belt
Island Arc
Bahamas
Basin
? ?
Fm. Guayo
Fm. Río Culebrinas
Formación Anon
Fm. Monserrate
Formación Mal Paso
Formación Palma Escrita

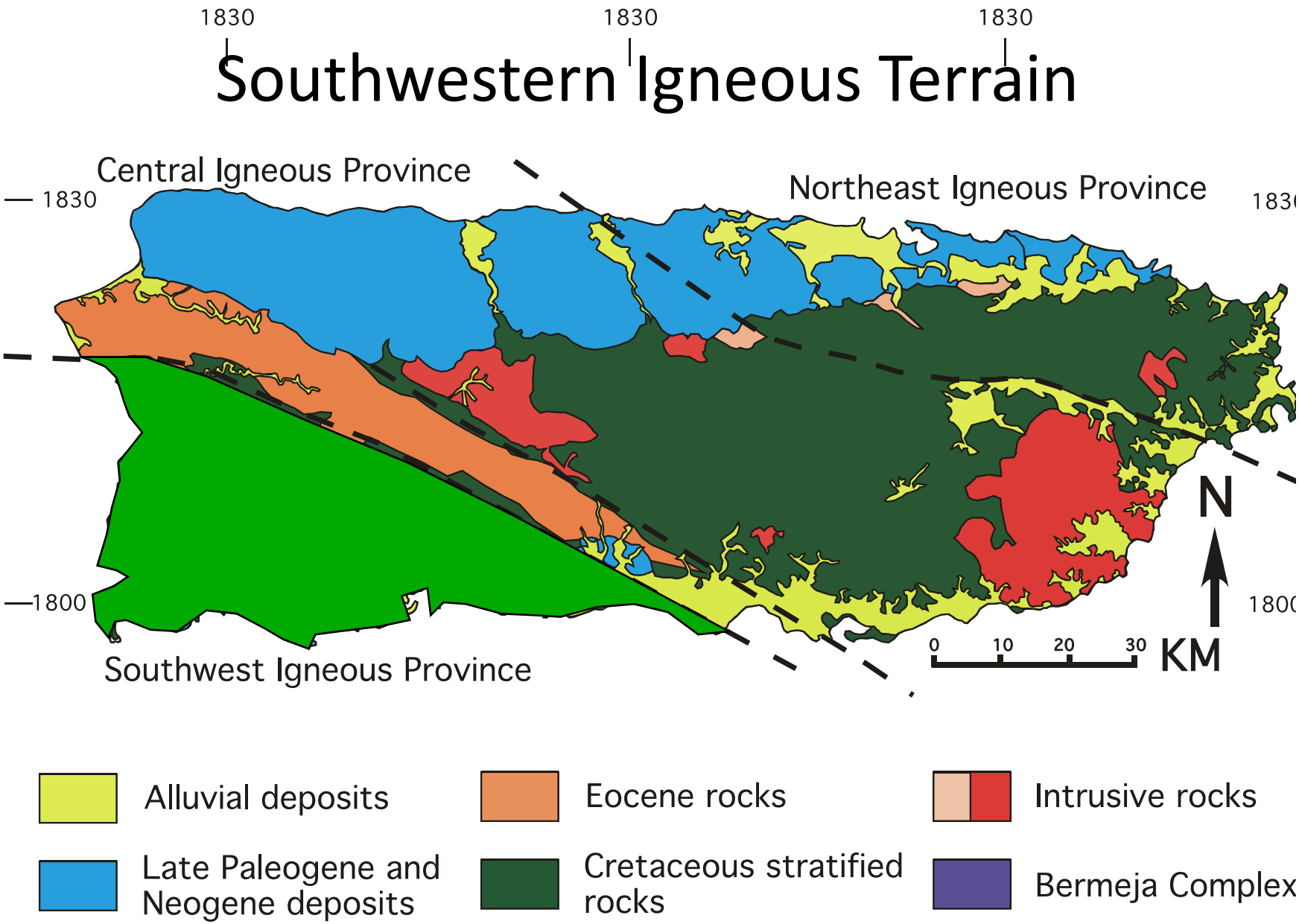
Monserrate Fm.
Ponce PR#139

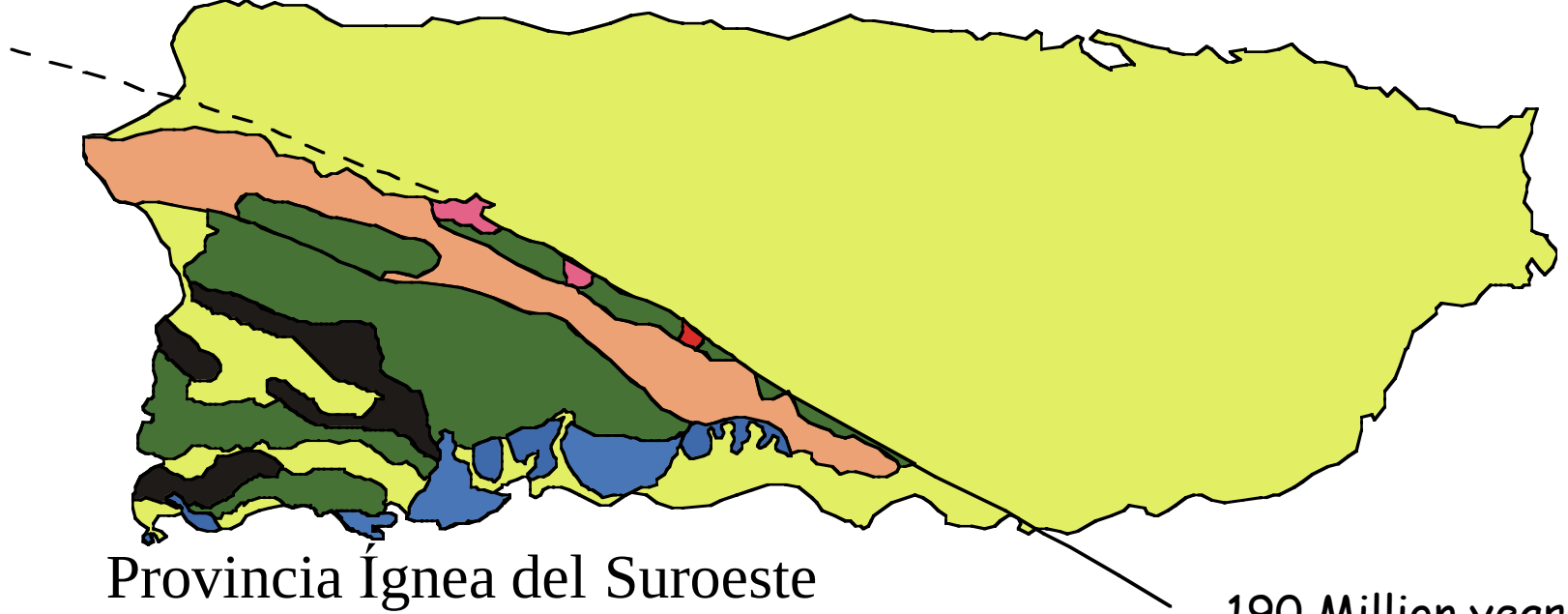


Eocene sedimentary rocks
Exposed at road PR-139
In Ponce

Mal Paso Fm.
Aguada, road PR-2

Southwestern Igneous Terrain

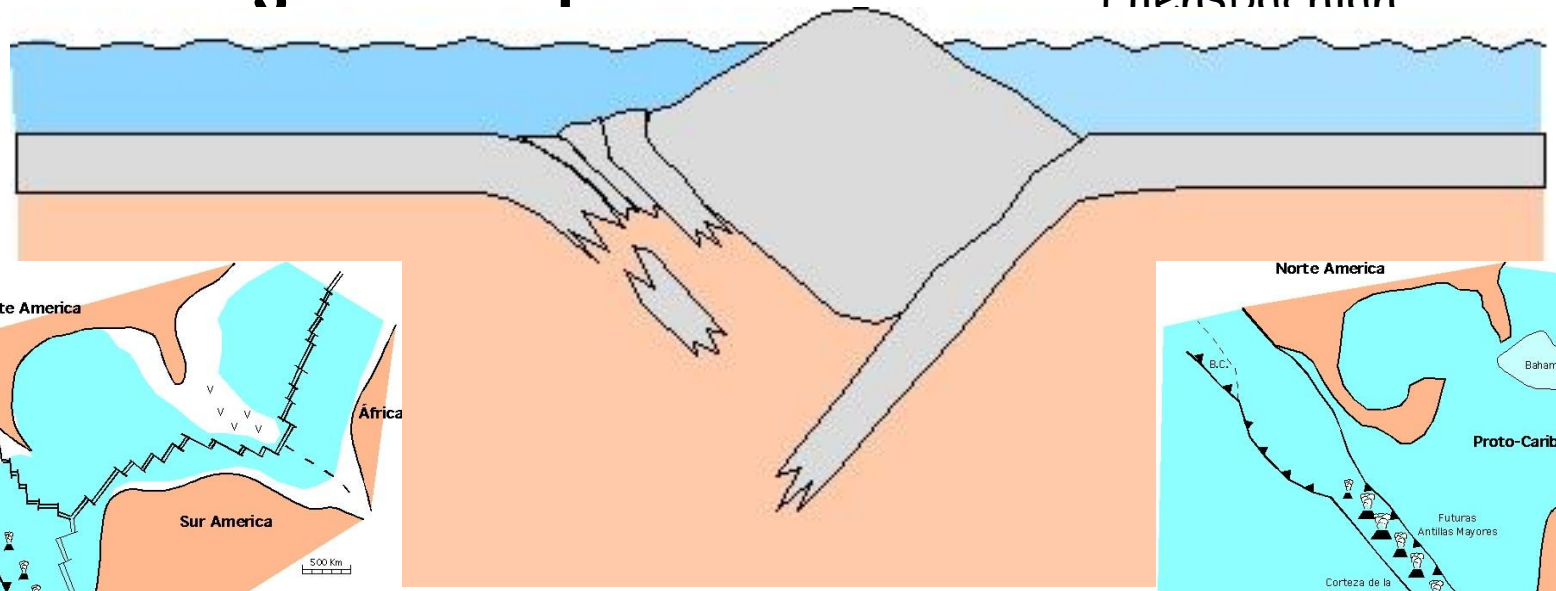


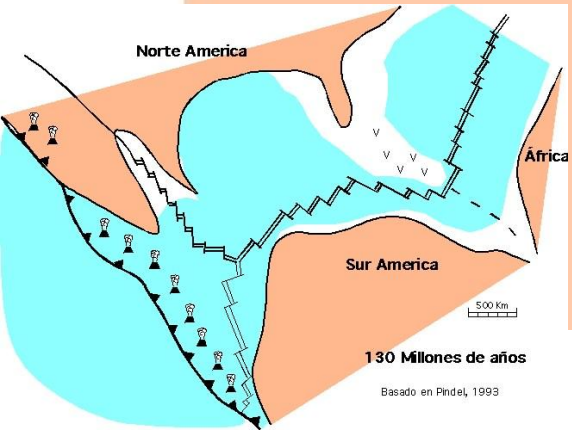


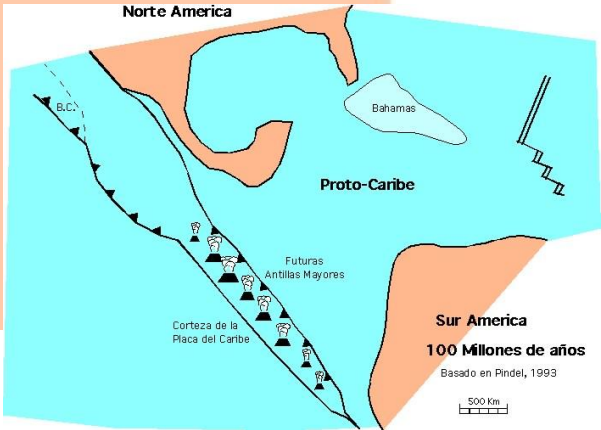
Provincia Ígnea del Suroeste

Bermeja Complex

190 Million years
Lower Jurassic
Pliensbachian





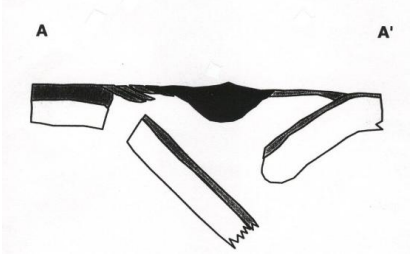


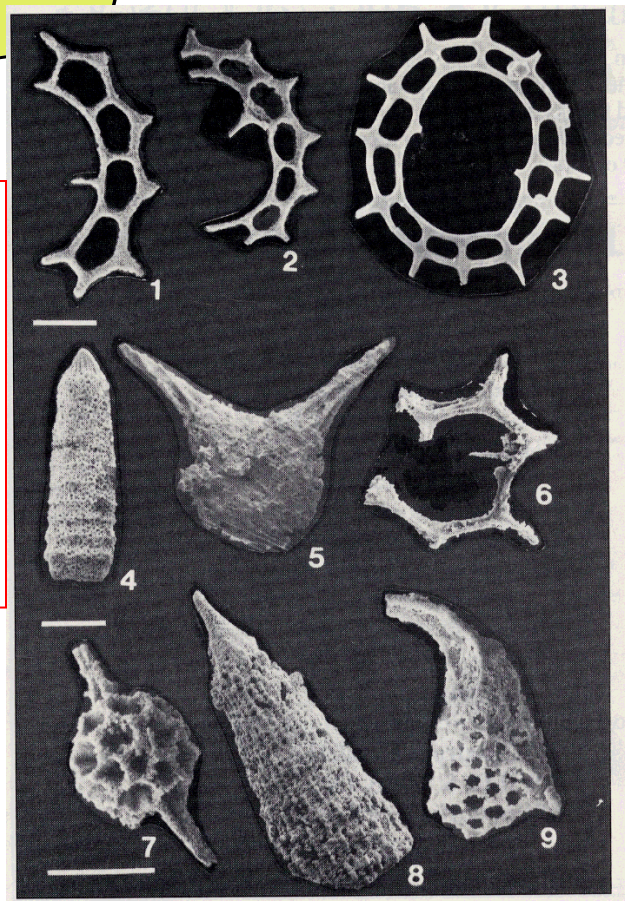
Bermeja Complex

195 Millones de años

Provincia Ígnea del Suroeste

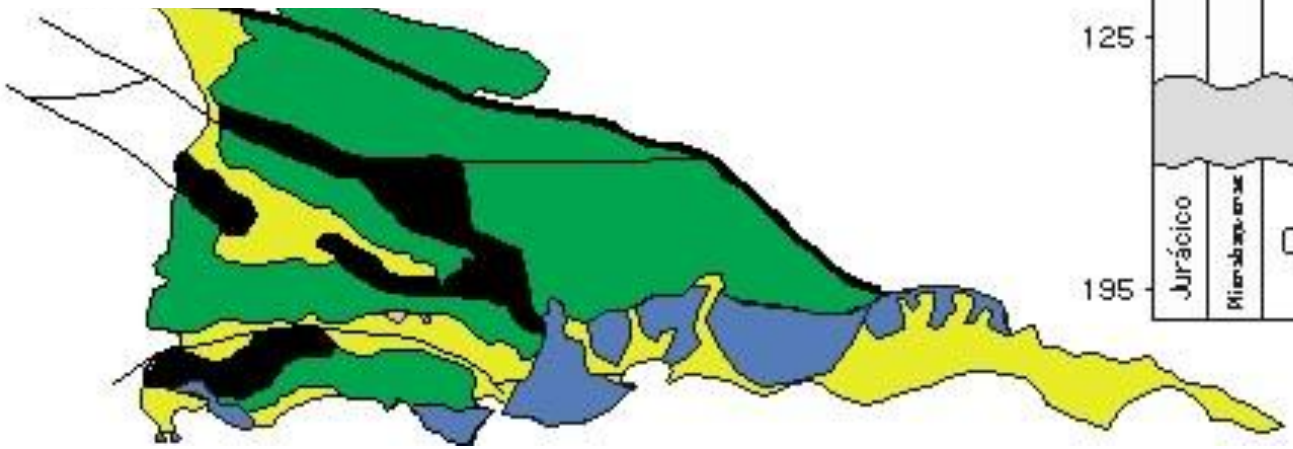
Deep marine sediments deposited at the sea-floor during the Jurassic to the Lower Cretaceous. Many of these rocks where deposited before volcanism started.

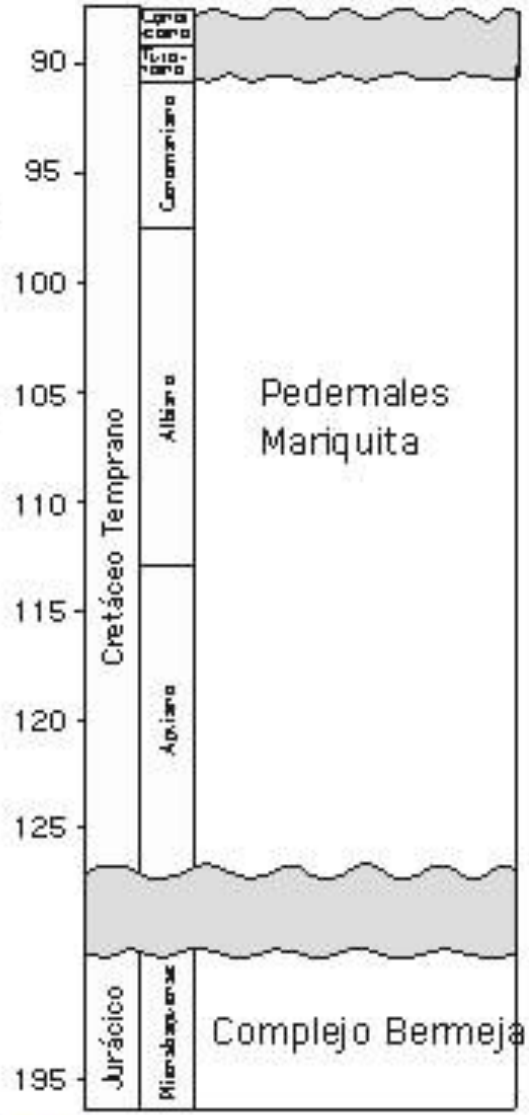




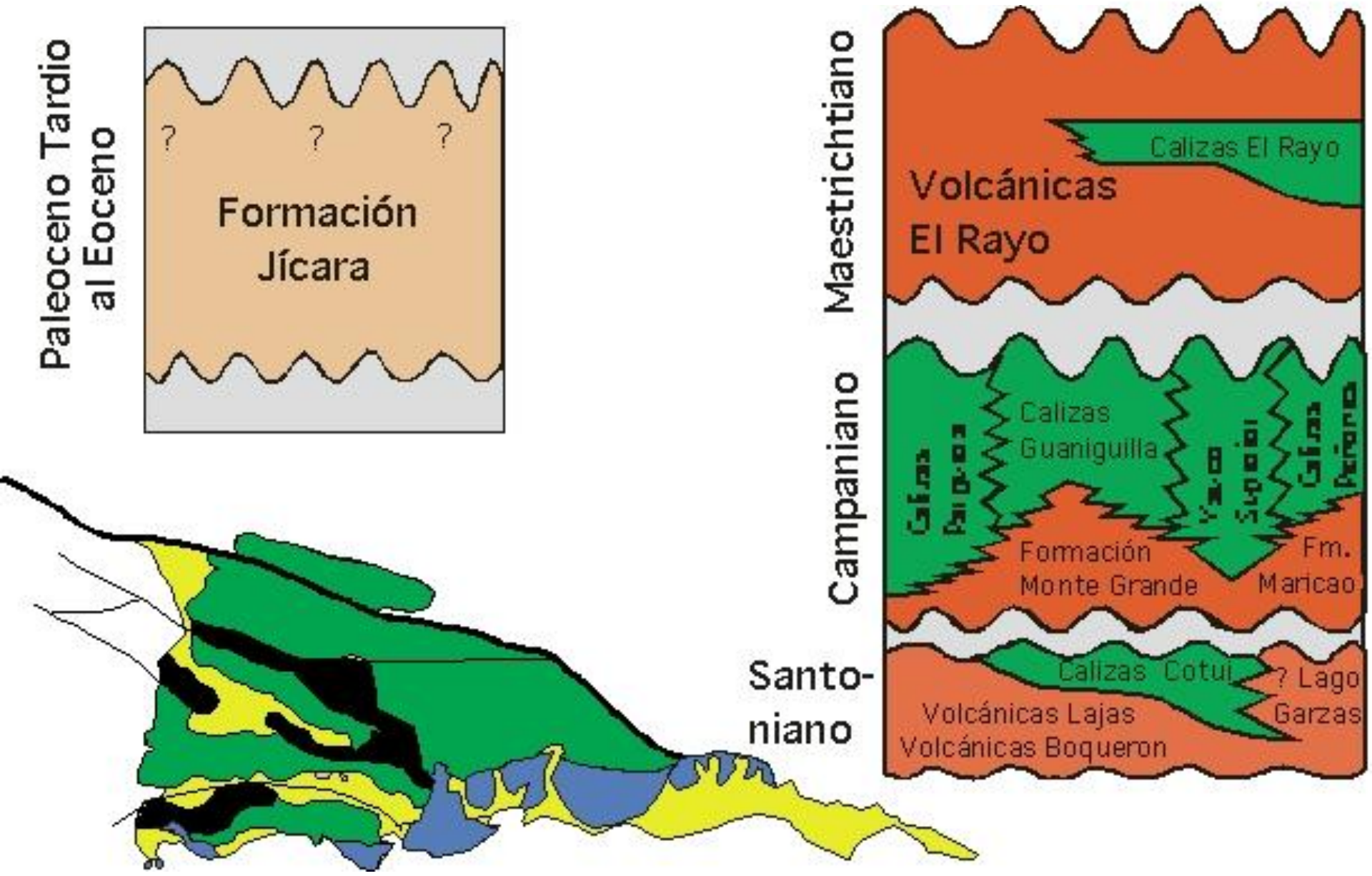
Southwestern Igneous Province

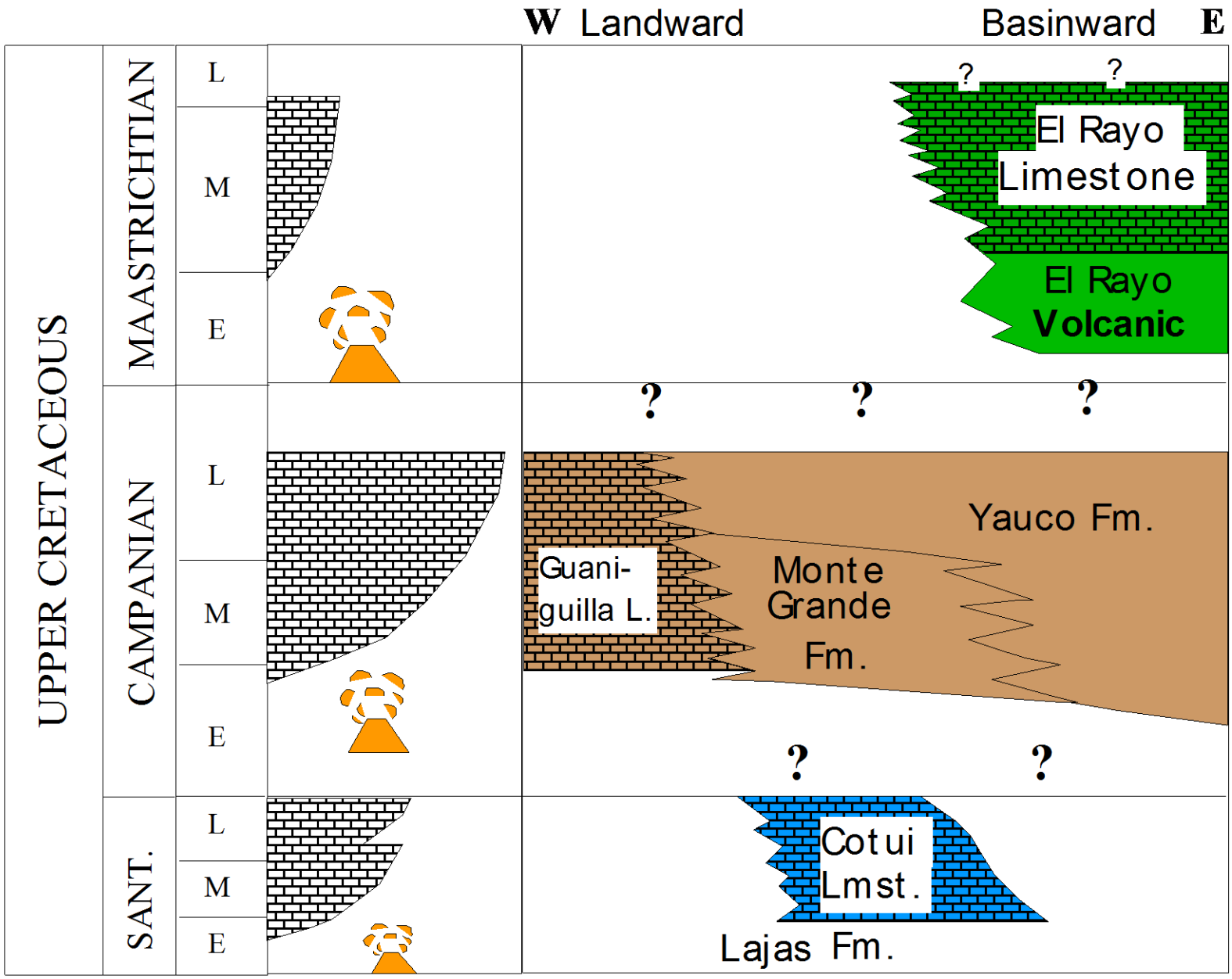
The Bermeja Complex is composed of chert, basalt, serpentinite, amphibolite and peridotite. The oldest rocks of Puerto Rico are here.

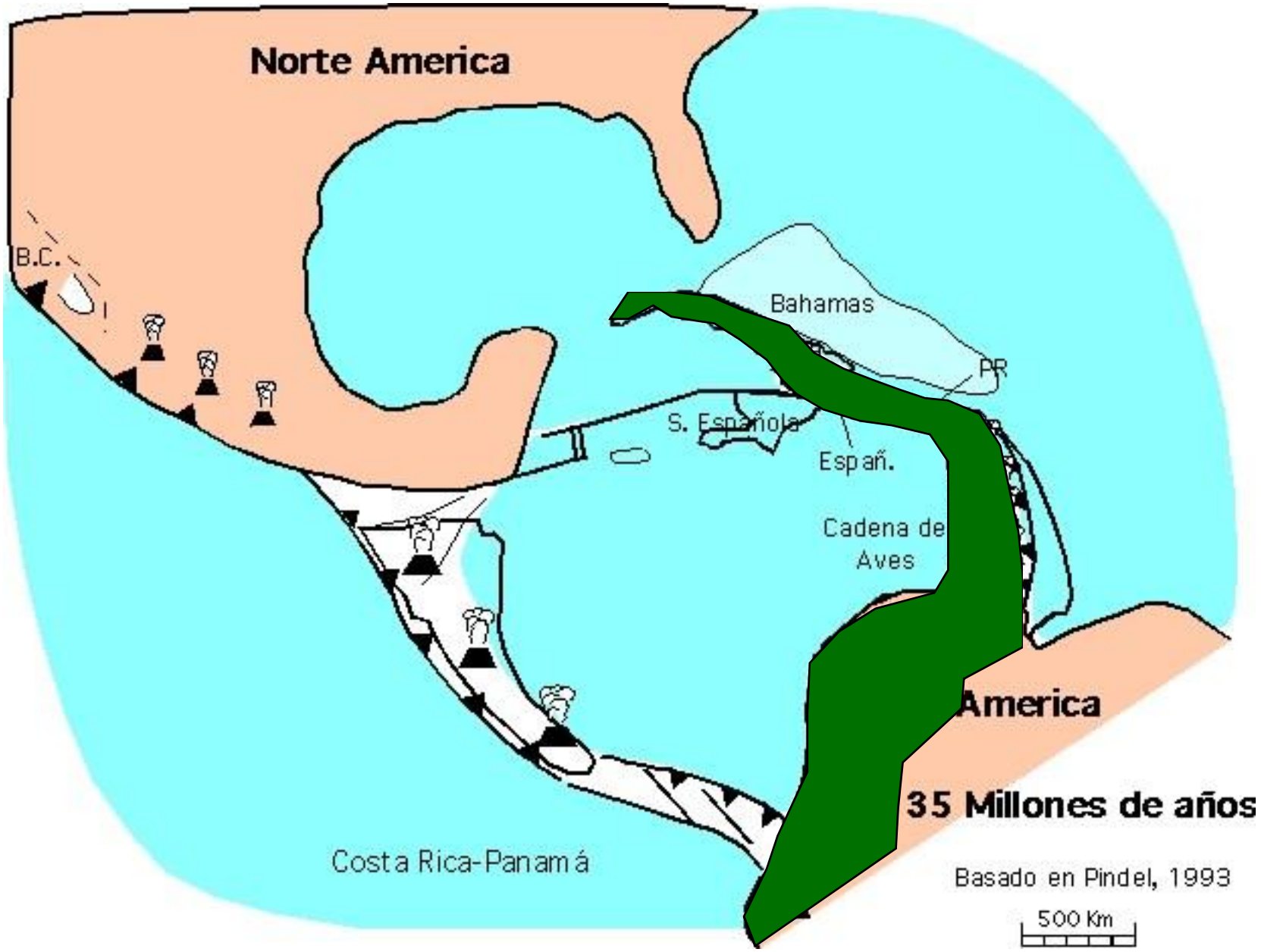




Southwestern Igneous Province




W Landward
Basinward E
UPPER CRETACEOUS
MAASTRICHTIAN
CAMPANIAN
SANT.
L
M
E
L
M
E
L
M
E
? ?
El Rayo
Limestone
El Rayo
Volcanic
? ? ?
Yauco Fm.
Guani-
guilla L.
Monte
Grande
Fm.
? ?
Cotui
Lmst.
Lajas Fm.


Norte America
B.C.
Bahamas
PR
S. Española
Españ.
Cadena de
Aves
America
35 Millones de años
Costa Rica-Panamá
Basado en Pindel, 1993
500 Km

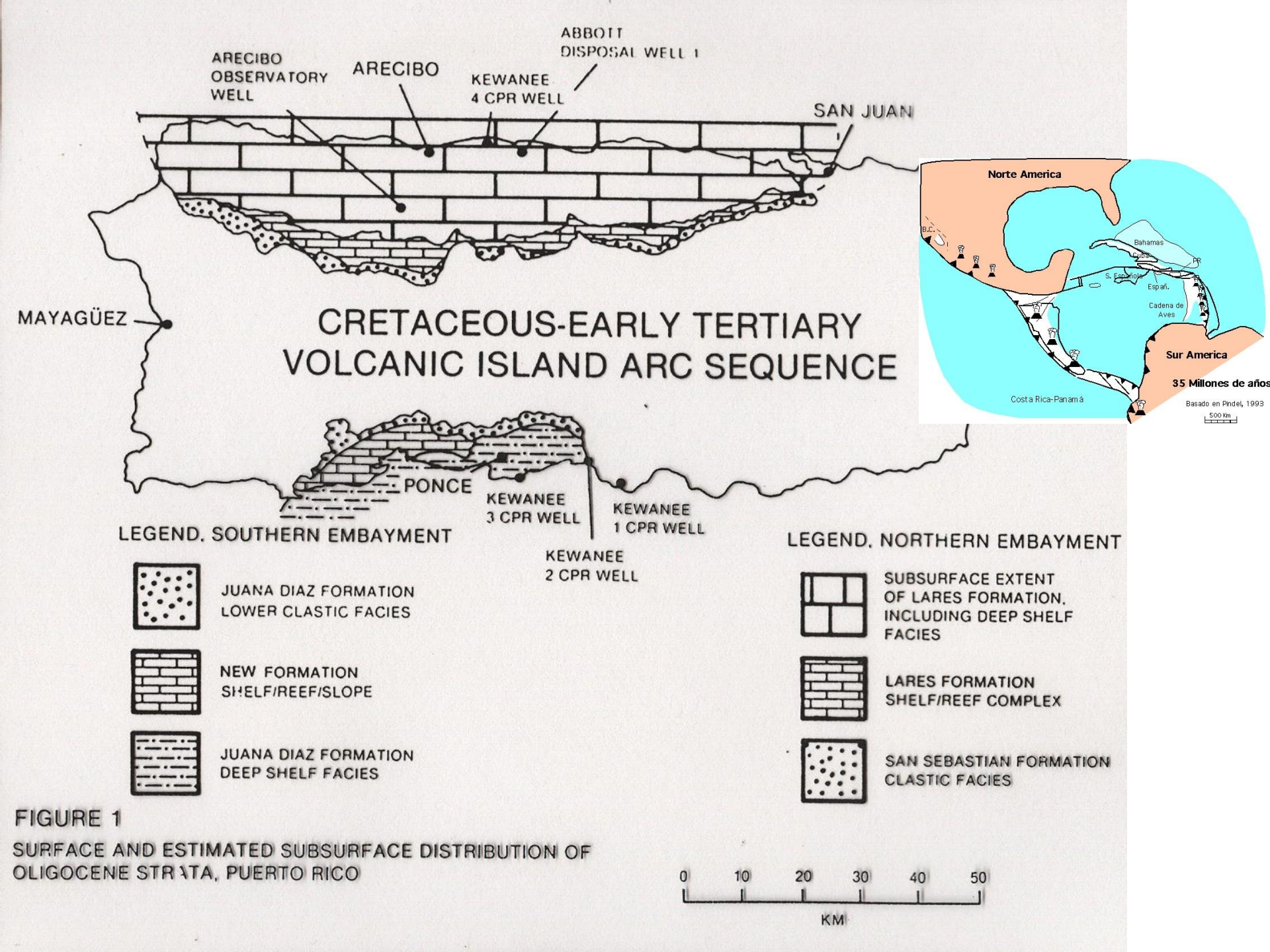
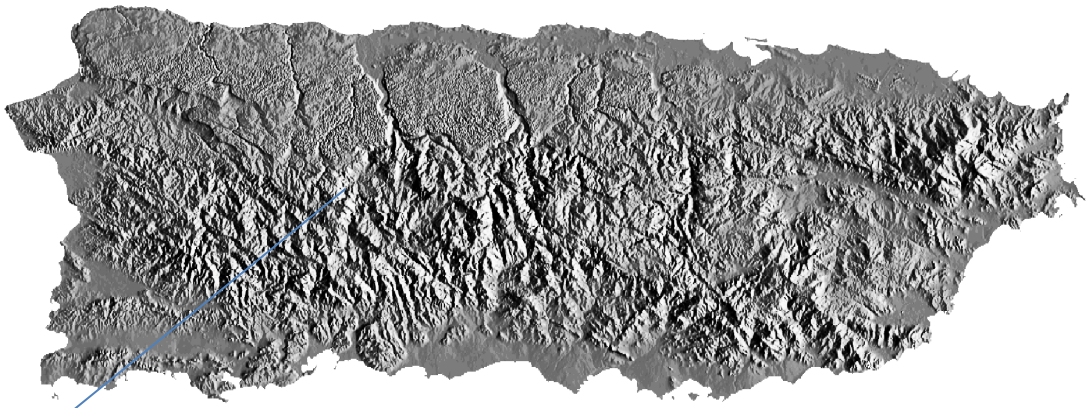


FIGURE 1

SURFACE AND ESTIMATED SUBSURFACE DISTRIBUTION OF OLIGOCENE STRATA, PUERTO RICO

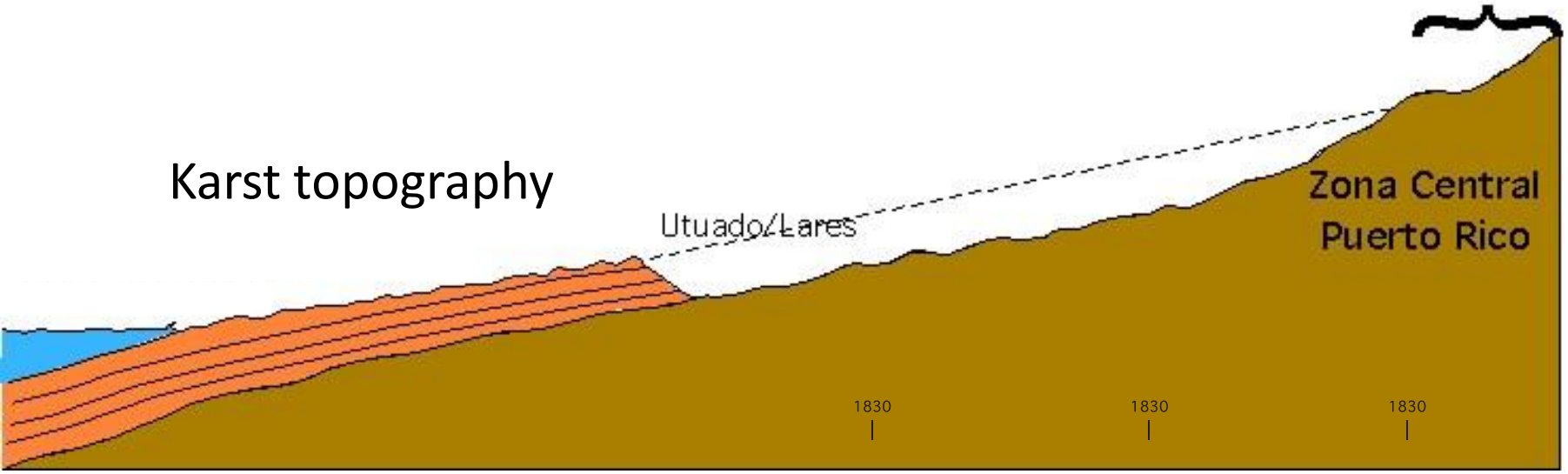
< N

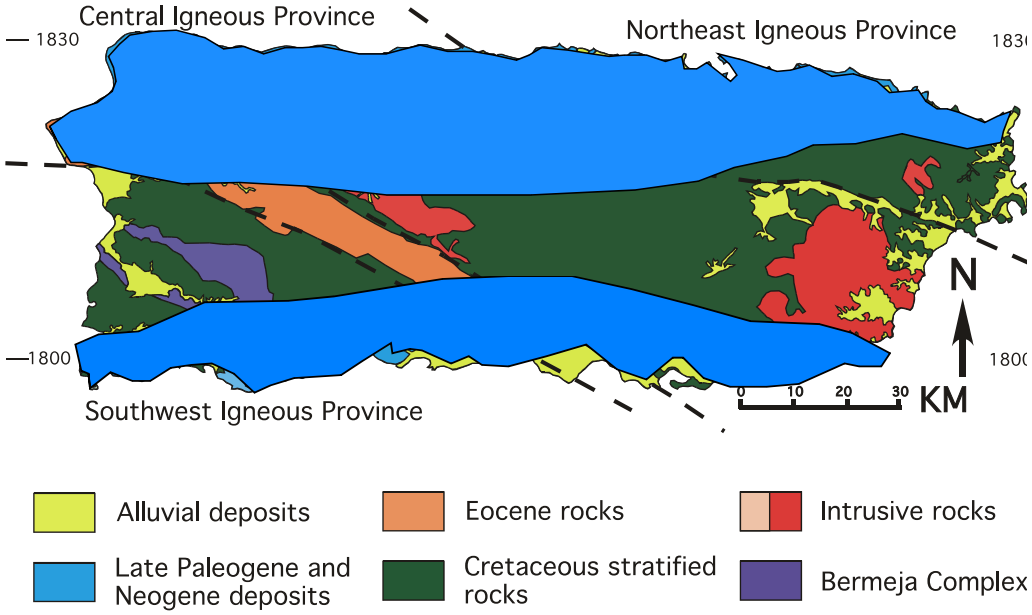


Limestone escarpment; the limestone represents shallow to open marine.

Cretaceous to Eocene Rocks

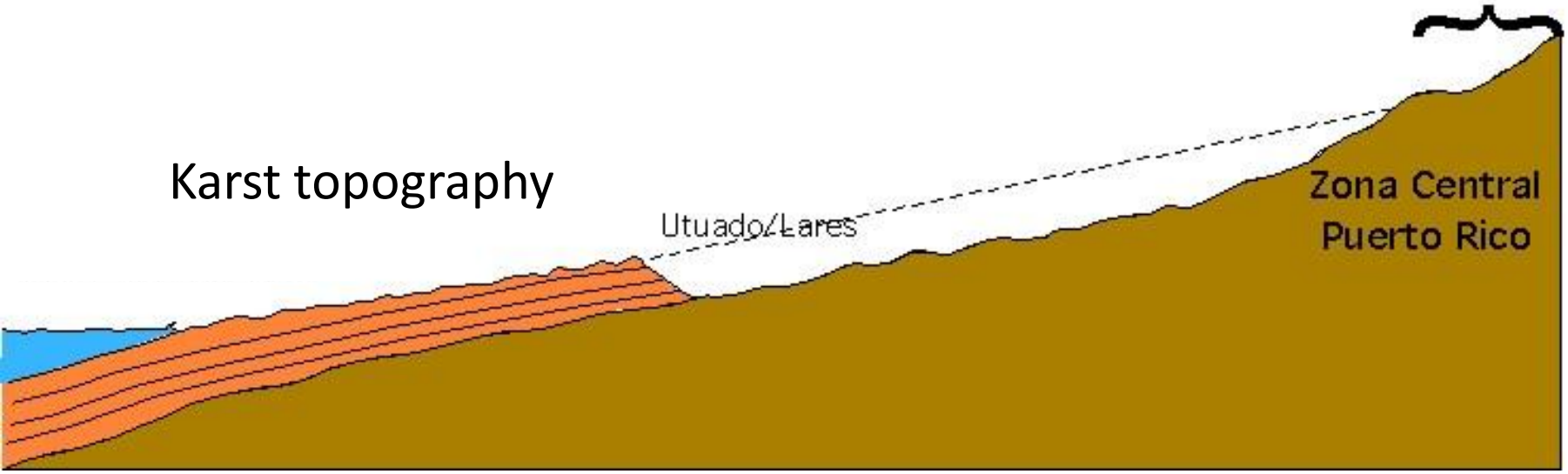
Karst topography





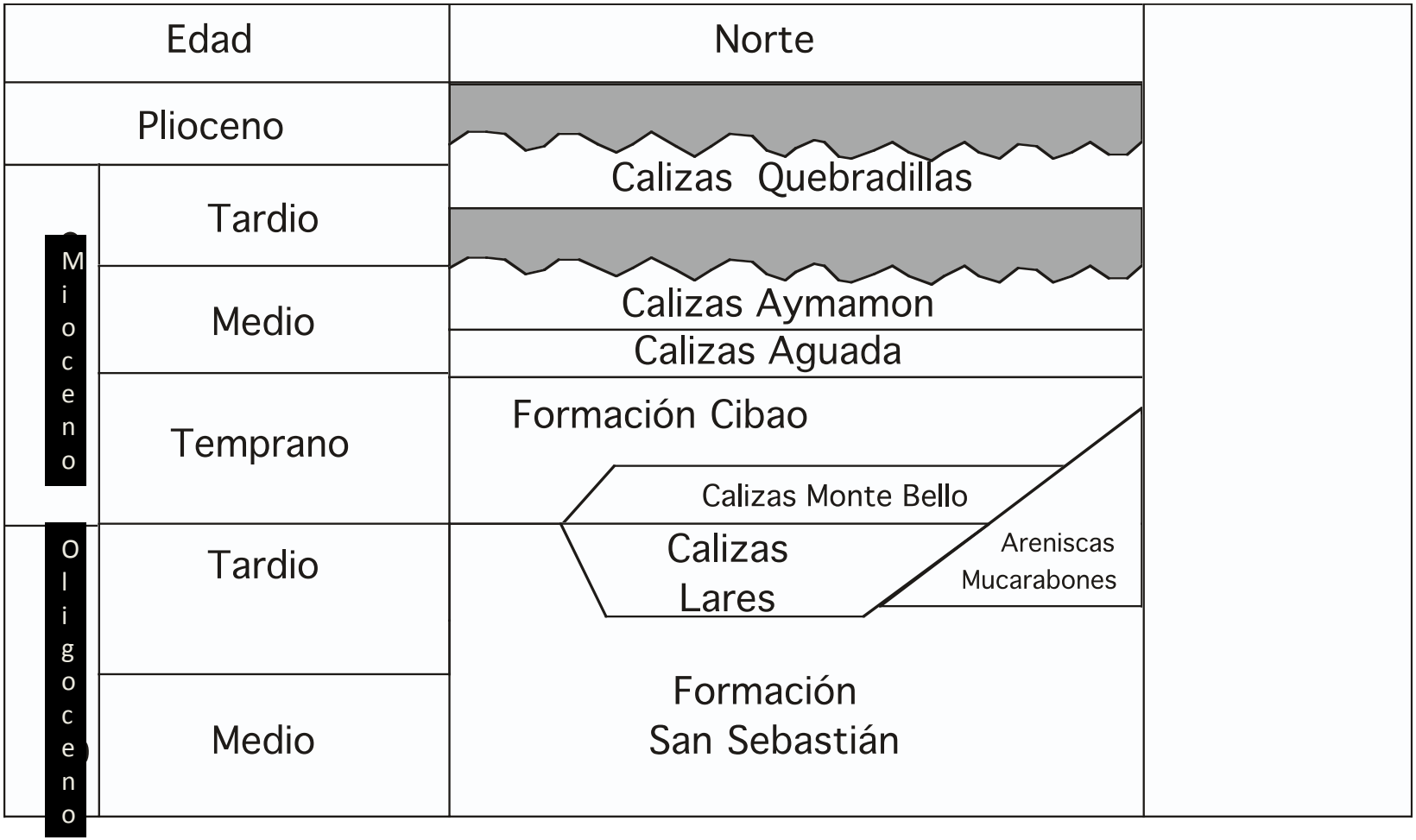
Cretaceous to Eocene Rocks

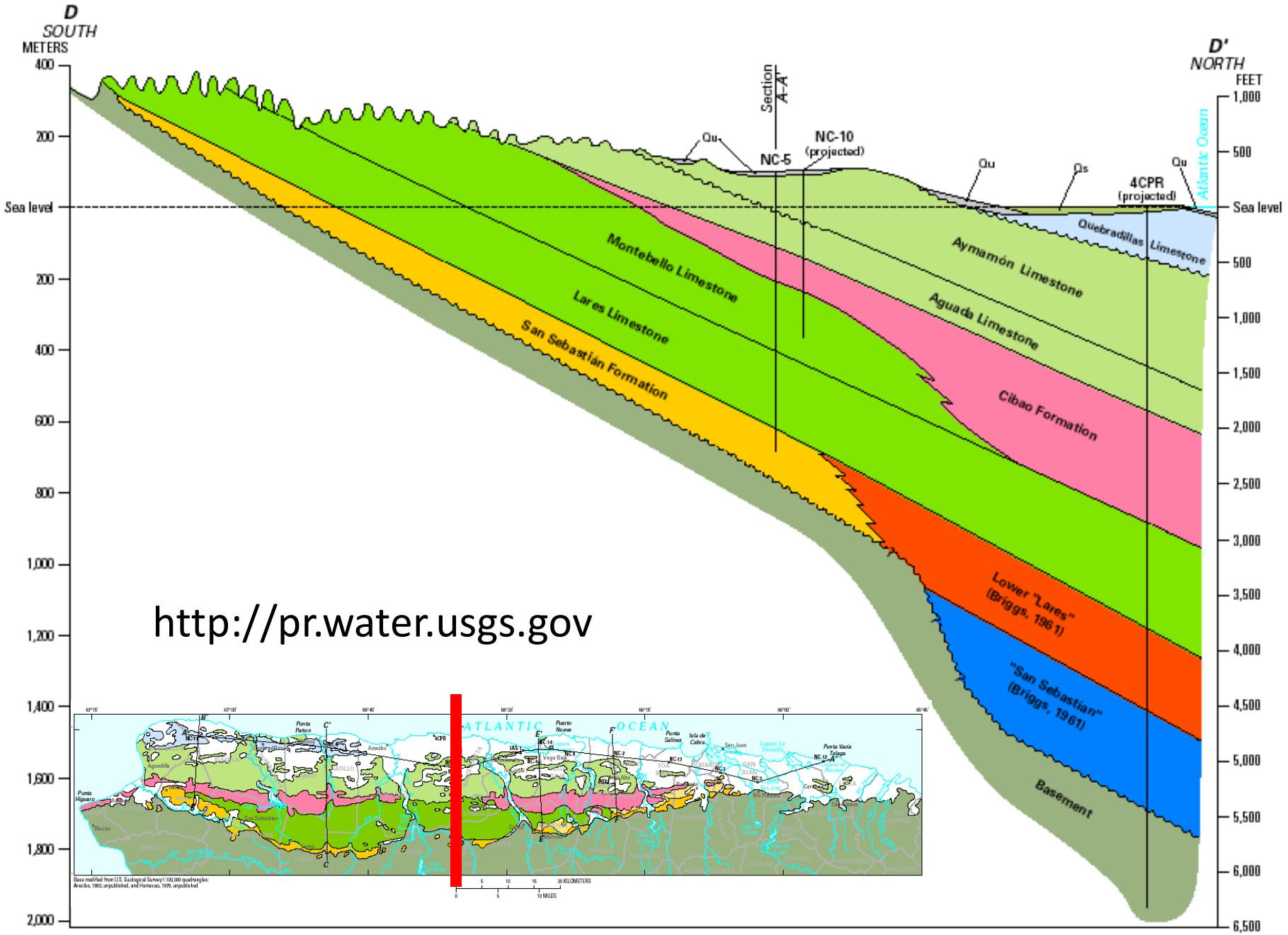
Karst topography



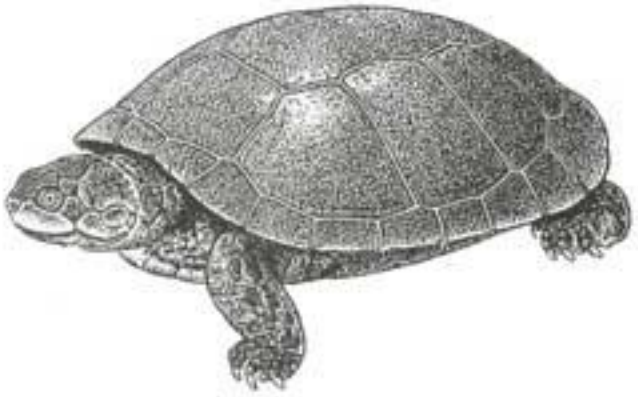
S

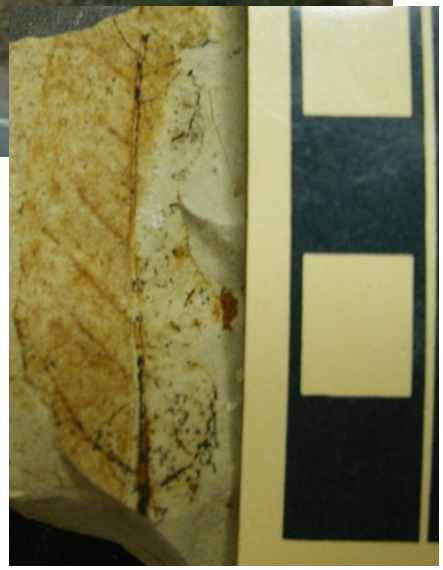
N


Edad
Norte
Plioceno
Tardio
Mioceno
Medio
Temprano
Tardio
Oligoceno
Medio
Calizas Quebradillas
Calizas Aymamon
Calizas Aguada
Formación Cibao
Calizas Monte Bello
Calizas
Lares
Areniscas
Mucarabones
Formación
San Sebastián

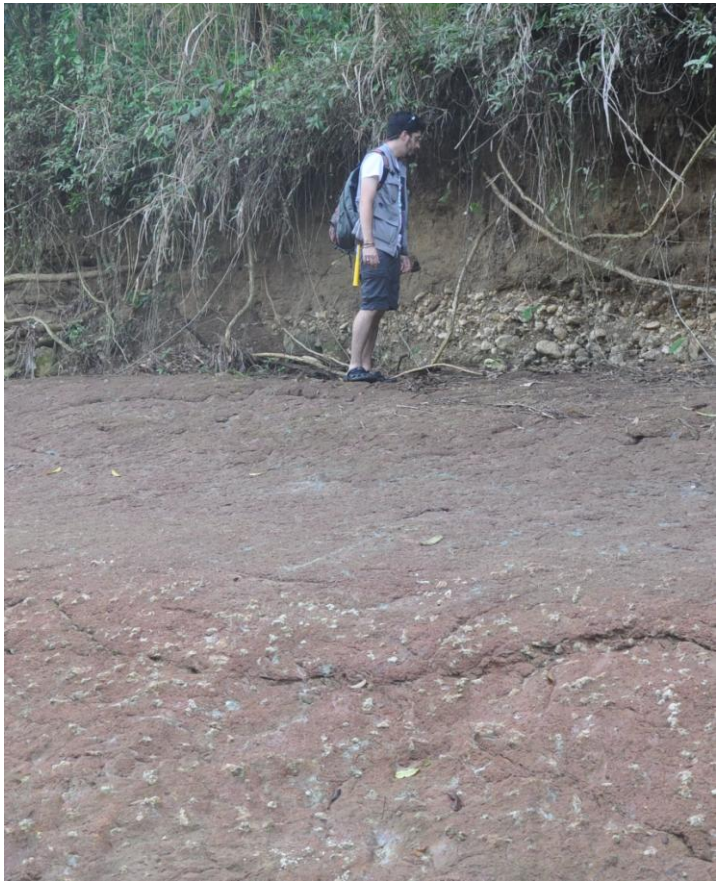

D
SOUTH
METERS
D'
NORTH
FEET
Section A-A'
NC-5
NC-10
(projected)
4CPR
(projected)
Qu
Qs
Atlantic Ocean
Sea level
Quebradillas Limestone
Aymamón Limestone
Aguada Limestone
Cibao Formation
Montebello Limestone
Lares Limestone
San Sebastián Formation
Lower "Lares"
(Briggs, 1961)
"San Sebastian"
(Briggs, 1961)
Basement
http://pr.water.usgs.gov
ATLANTIC OCEAN

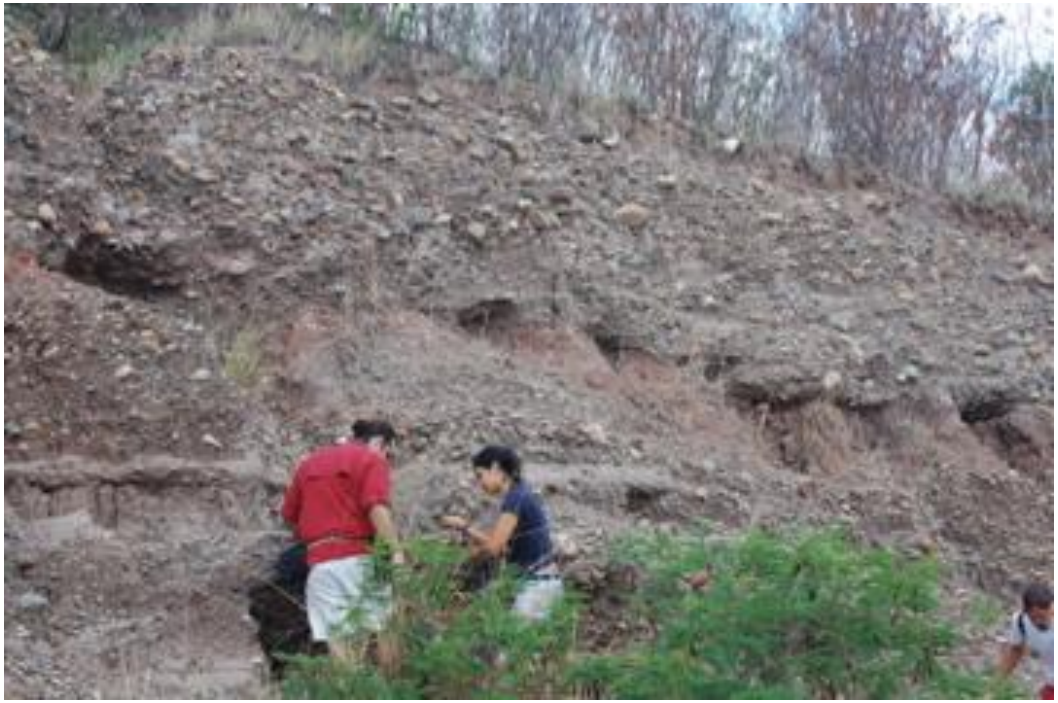
Juana Díaz Fm. Yauco





Conglomerates y paleosols





Paleosols of the San Sebastián Fm.

Croc tooth

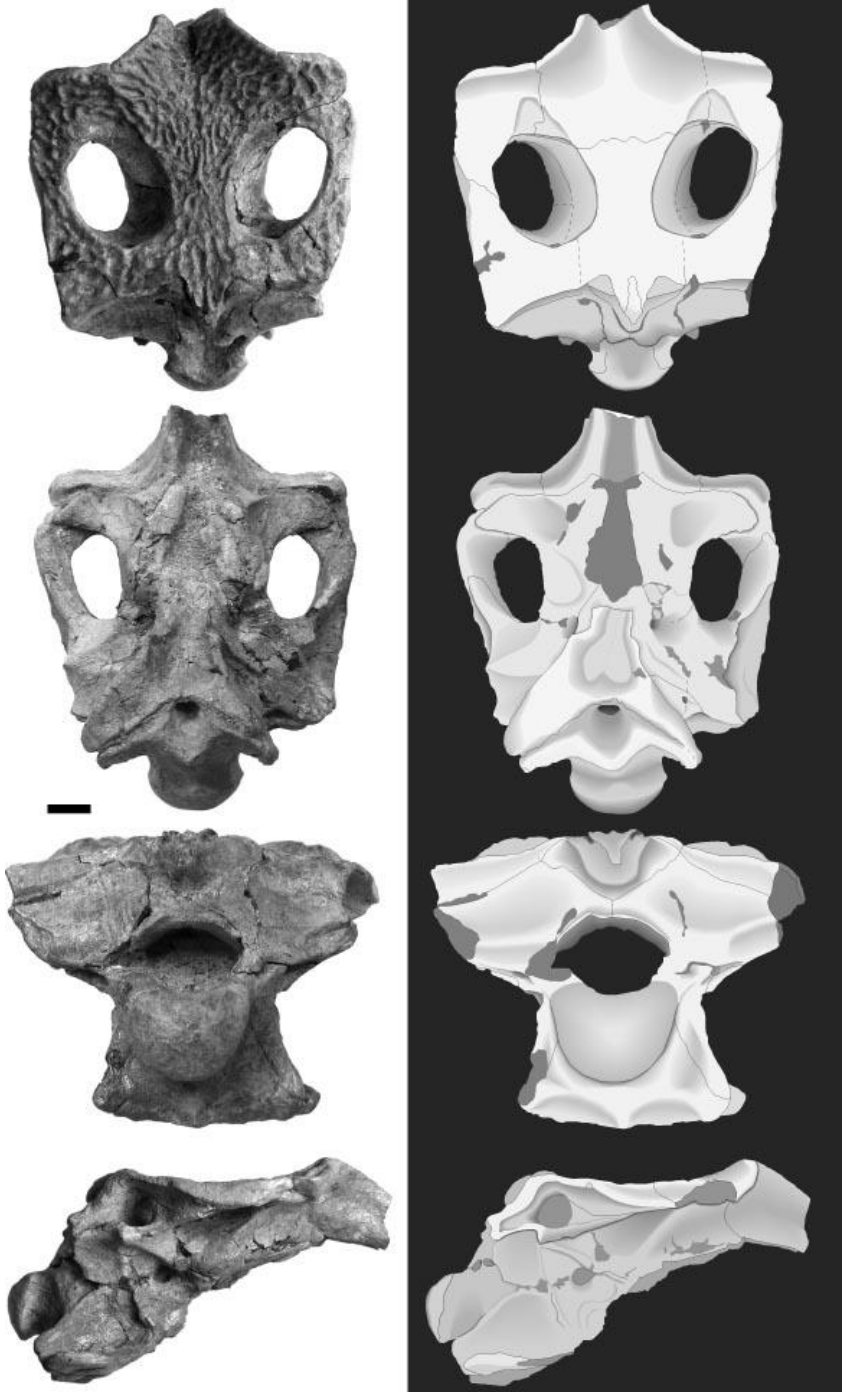
Formation: Lares Lms

Age: L. Oligocene – E. Miocene

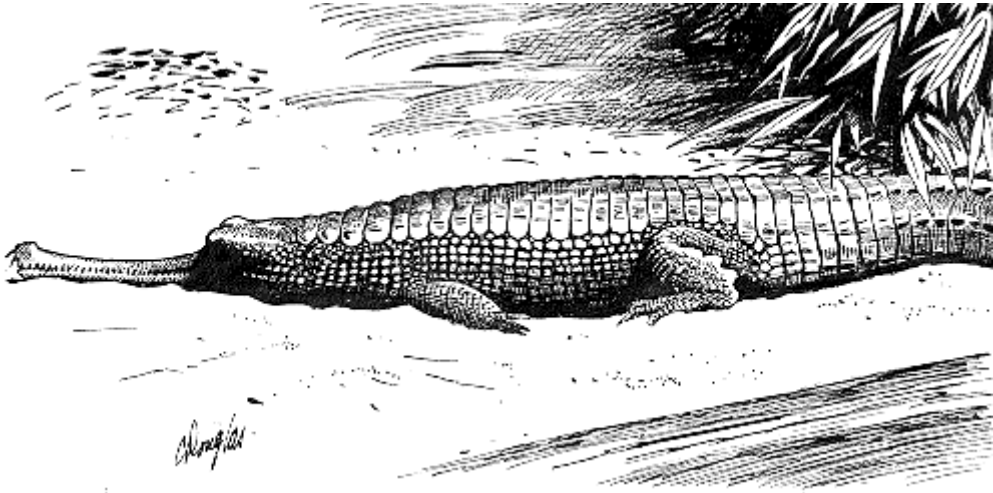
Locality: PR-111, San Sebastian

Dimension: 2.1 cm tall

Crocodile of the Lares Fm.

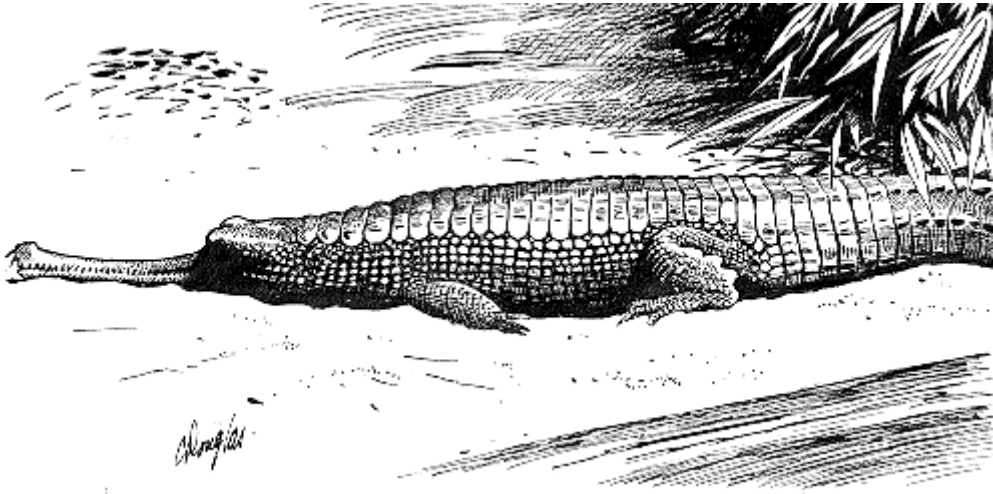


Gavialis




Gavial (Gavialidae)
Reptiles Alligators
IMAGE BY: WERNHER KRUTEIN
PHOTOVAULT ©

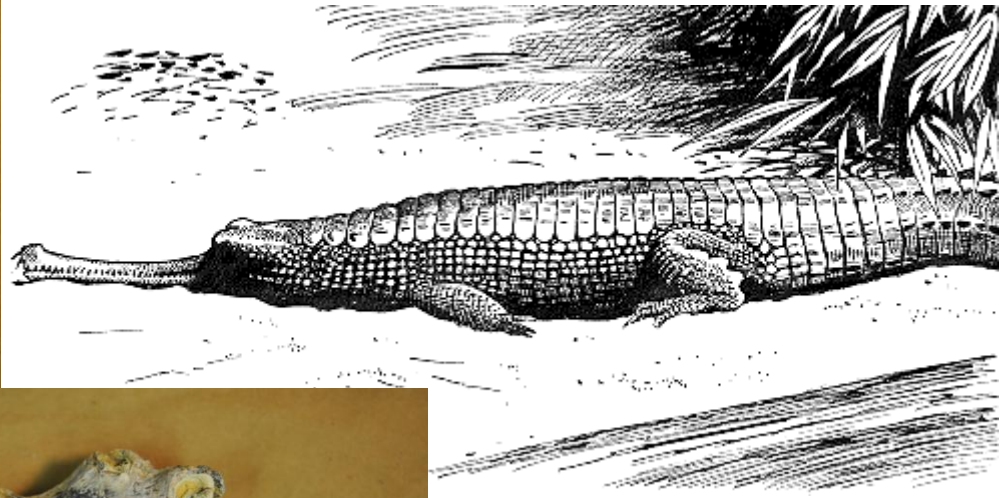
Gavialis



Gavialis gangeticus

https://en.wikipedia.org/wiki/Gavialis

Gavialis




Calizas Monte Bello
Calizas Lares

Formación Calizas Ponce

Formación Calizas Ponce

Schizaster sp.

Formation: Aymamon Lms

Age: Middle Miocene

Locality: Isabela

Kuphus incrassata

Formation: Ponce Lms.

Clypeaster sp.

Formation: Ponce Lms

Age: Miocene

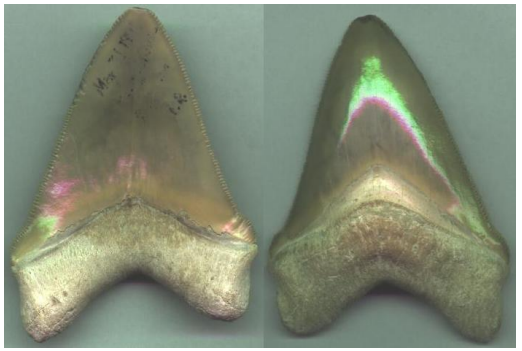
Locality: Ponce

Spondylus sp.

Formation: Ponce Lms

Age: Miocene

Locality: Ponce



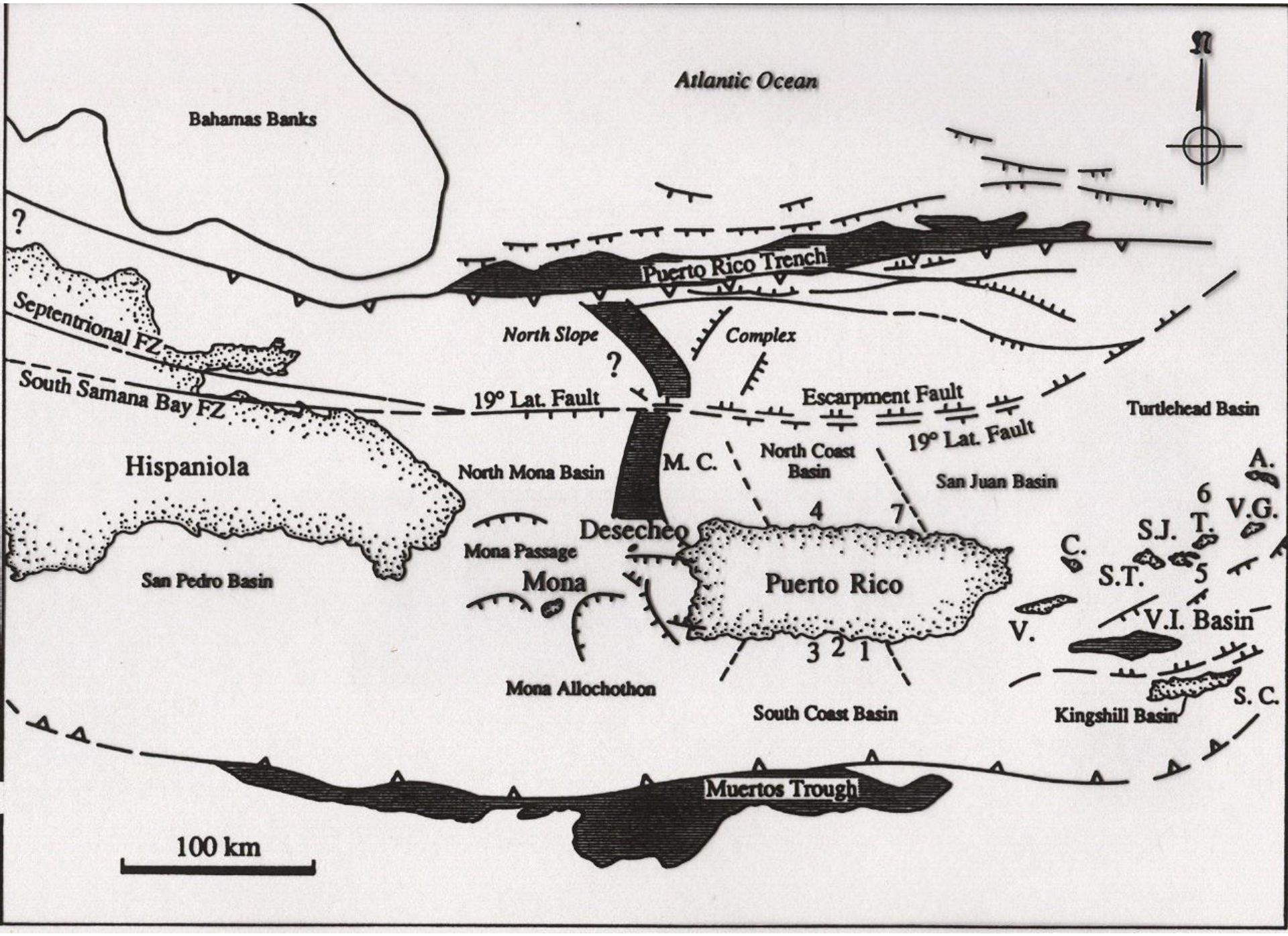
Carcharodon subauriculatus

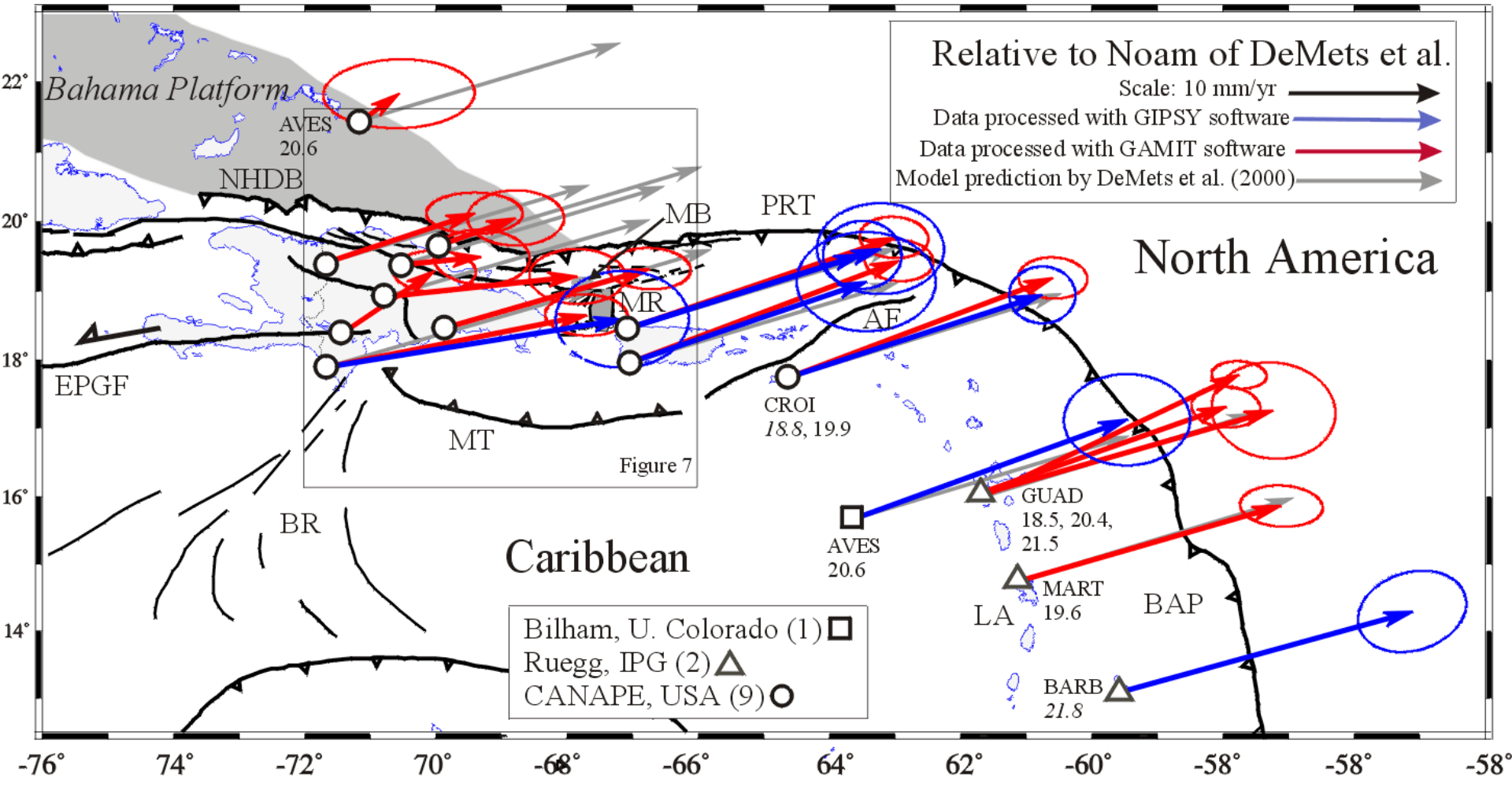
Formation: Cibao Fm

Age: Early Miocene

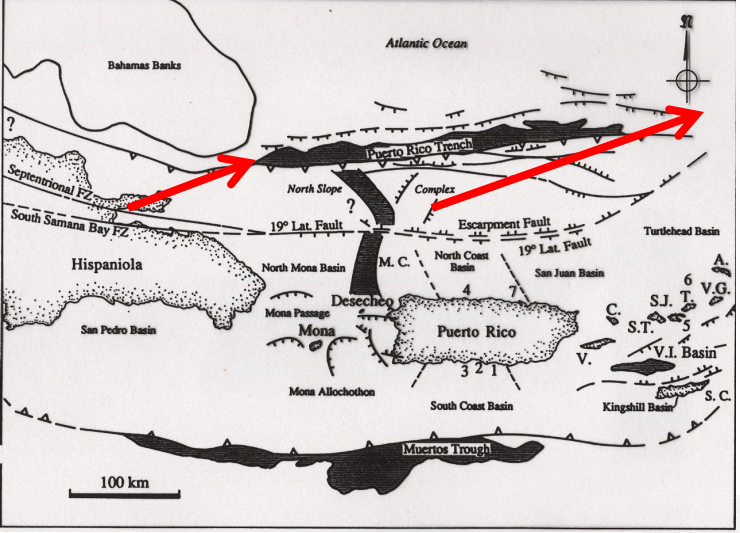
Locality: Bayamon

Dimension: 7.6 cm tall, 5.9 cm wide

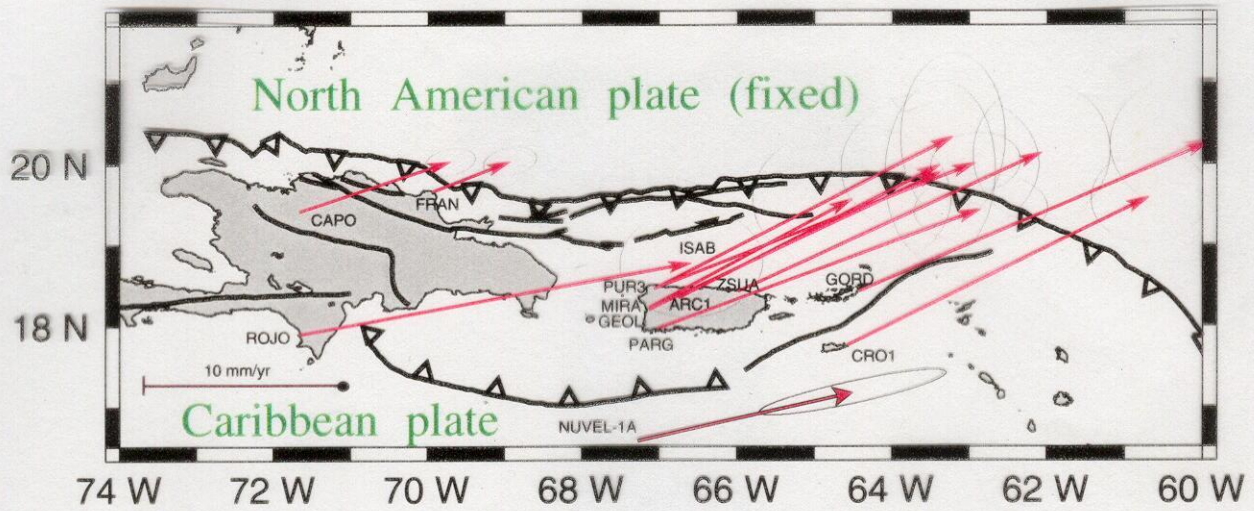

Atlantic Ocean
Bahamas Banks
?
Puerto Rico Trench
Septentrional FZ
South Samana Bay FZ
North Slope
Complex
?
19° Lat. Fault
Escarpment Fault
Turtlehead Basin
19° Lat. Fault
Hispaniola
North Mona Basin
M. C.
North Coast Basin
San Juan Basin
A.
6
V.G.
4
7
Desecheo
S.J.
T.
C.
Mona Passage
S.T.
5
San Pedro Basin
Mona
Puerto Rico
V.I. Basin
V.
3 2 1
Mona Allochothon
South Coast Basin
Kingshill Basin
S. C.
Muertos Trough
100 km



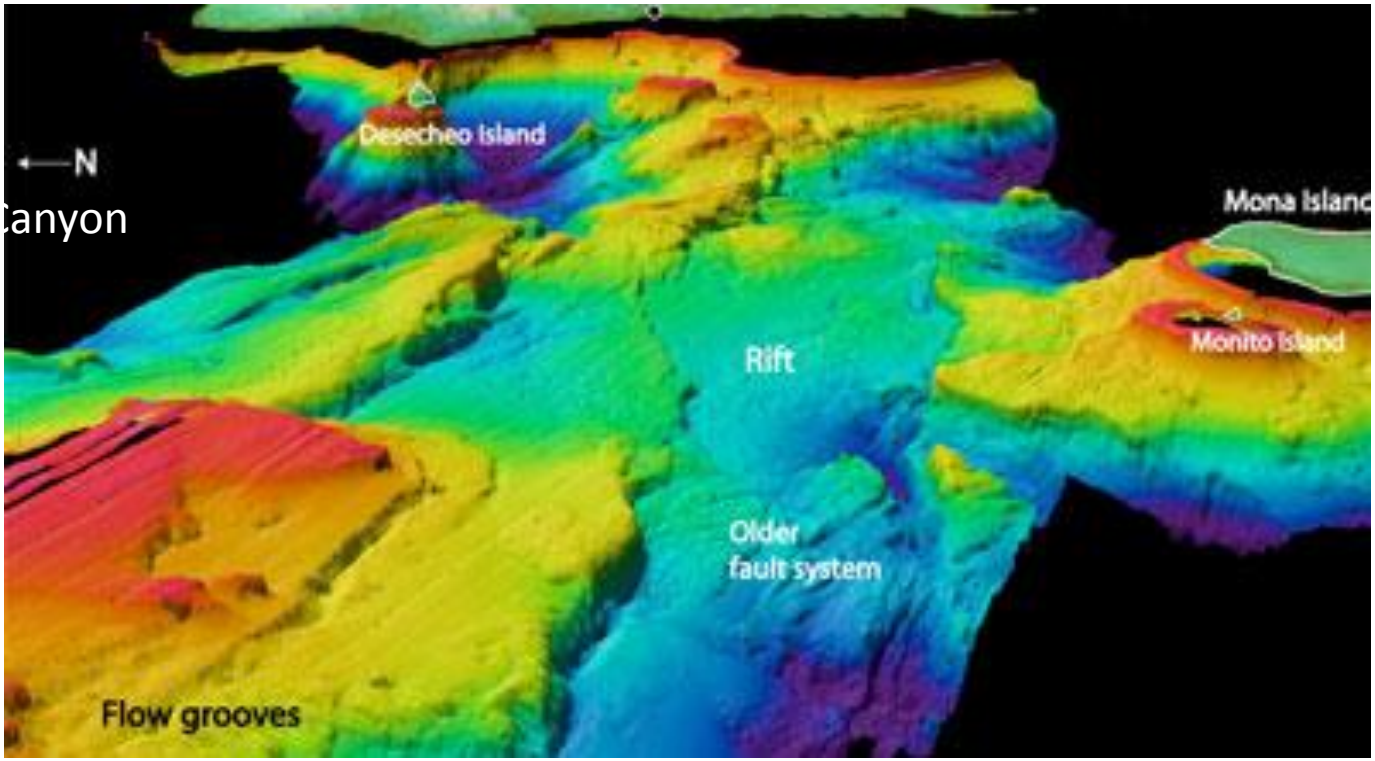
CANAPE Project (Caribbean North American Plate Experiment)



Velocities in northeastern Caribbean relative to NOAM



Bathymetric Map of Mona Passage



Uri ten Brink, 2007

Questions

?

Puerto Rico 1918

Significant Earthquake of Puerto Rico

- 1670
  - MM = VII, San Germán y San Juan
- 1787
  - M @7-8,MM = VII-VIII, North Coast, East y West
- 1867
  - M =7.3, MM = VIII, Vírgen Islands, East of Puerto Rico, Tsunami 20’
- 1918
  - M = 7.3, MM = VIII, west Coast of PR, Tsunami 20’
- 1943
  - M = 7.5, MM = V, Northeast of Puerto Rico

Damaged houses by the Tsunami Mayagüez.

1918 Earthquake

The island of Puerto Rico was hit by strong earthquake in October 11, 1918 at 10:14 A.M.

According to records 116 persons lost their live and about 4 million dollars in property damage (a big amount for the time).

House in Mayagüez with a collapse brick roof. A concrete broken telephone pole can be seen in front of the house. The damaged towers of the catholic churches can be seen in the bag.

SISMIC NETWORK OF PUERTO RICO

SISMIC NETWORK OF PUERTO RICO

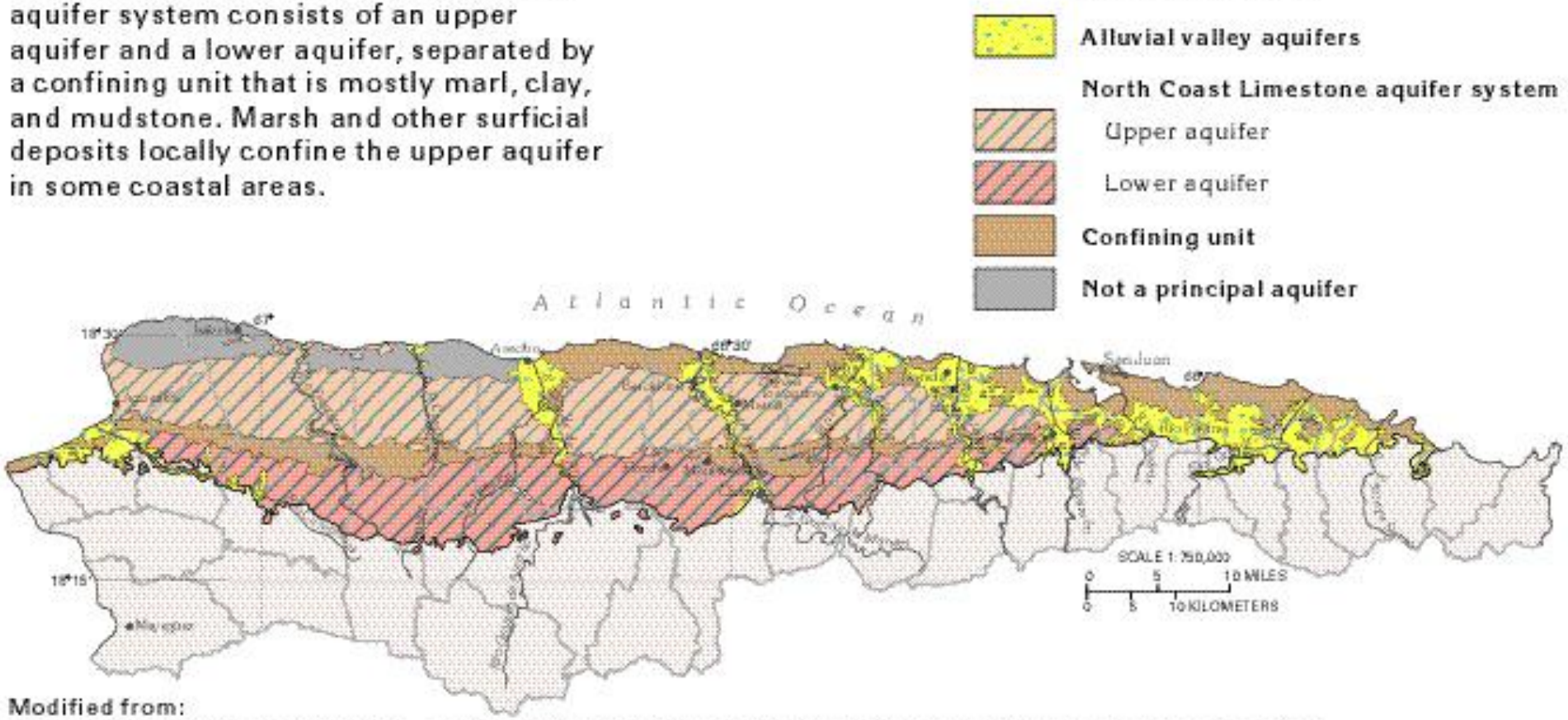
Several bricks buildings damaged by the earthquake in Mayagüez.

In Aguadilla 32 persons were drowned by the tsunami. About 300 small houses were destroyed.

Debris in the beach of Mayagüez after the Tsunami. See the remains of the houses that were lift from their columns and carried away.

1918 Tsunami

Figure 101. The North Coast Limestone aquifer system consists of an upper aquifer and a lower aquifer, separated by a confining unit that is mostly marl, clay, and mudstone. Marsh and other surficial deposits locally confine the upper aquifer in some coastal areas.

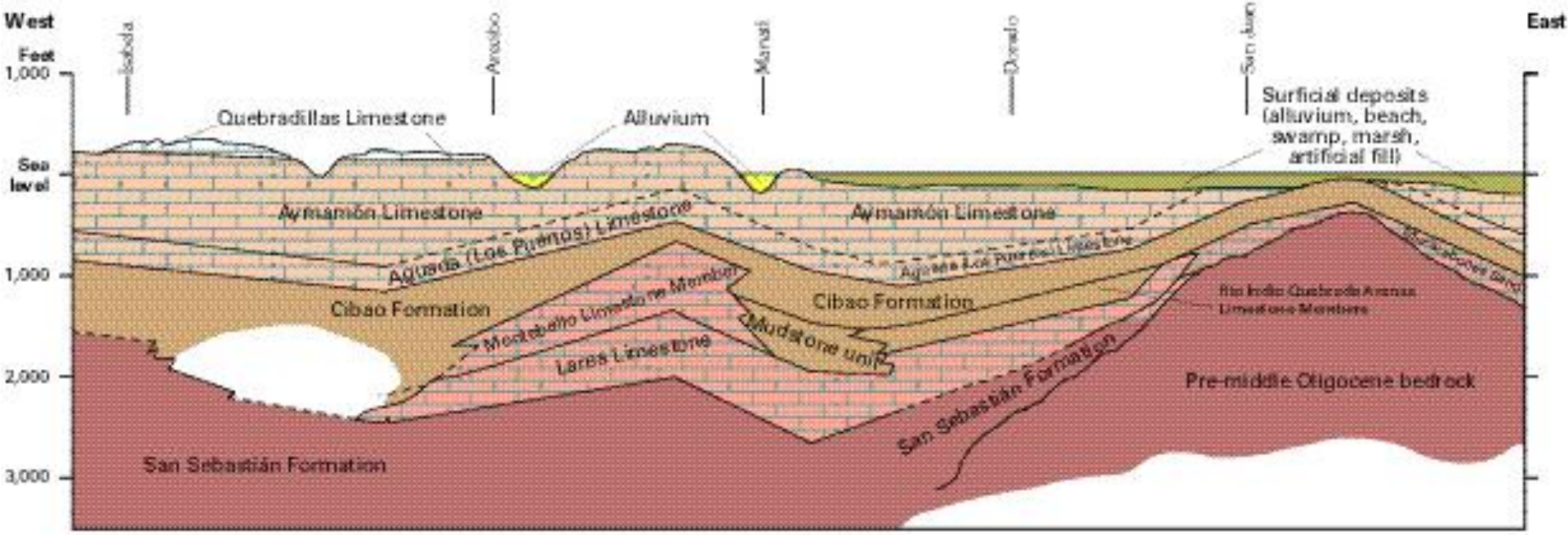


Modified from:

Renken, R.A., Rodríguez-Martínez, Jesús, and Gómez-Gómez, Fernando, in press, Hydrogeologic framework of the U.S. Caribbean Islands in Renken, R.A., Ward, W.C., Gill, I.P.

Rodríguez-Martínez, Jesús, and others, Geology and hydrology of the Caribbean Islands aquifer system of the Commonwealth of Puerto Rico and the U.S. Virgin Islands: U.S. Geological Survey Professional Paper 1419.

Base modified from U.S. Geological Survey digital data



EXPLANATION

- Alluvial valley aquifer
- Local confining unit
- Unsaturated (nonaquifer)
- North Coast Limestone aquifer system
  - Upper aquifer
  - Confining unit
  - Lower aquifer
- Basal confining unit

Geology modified from:

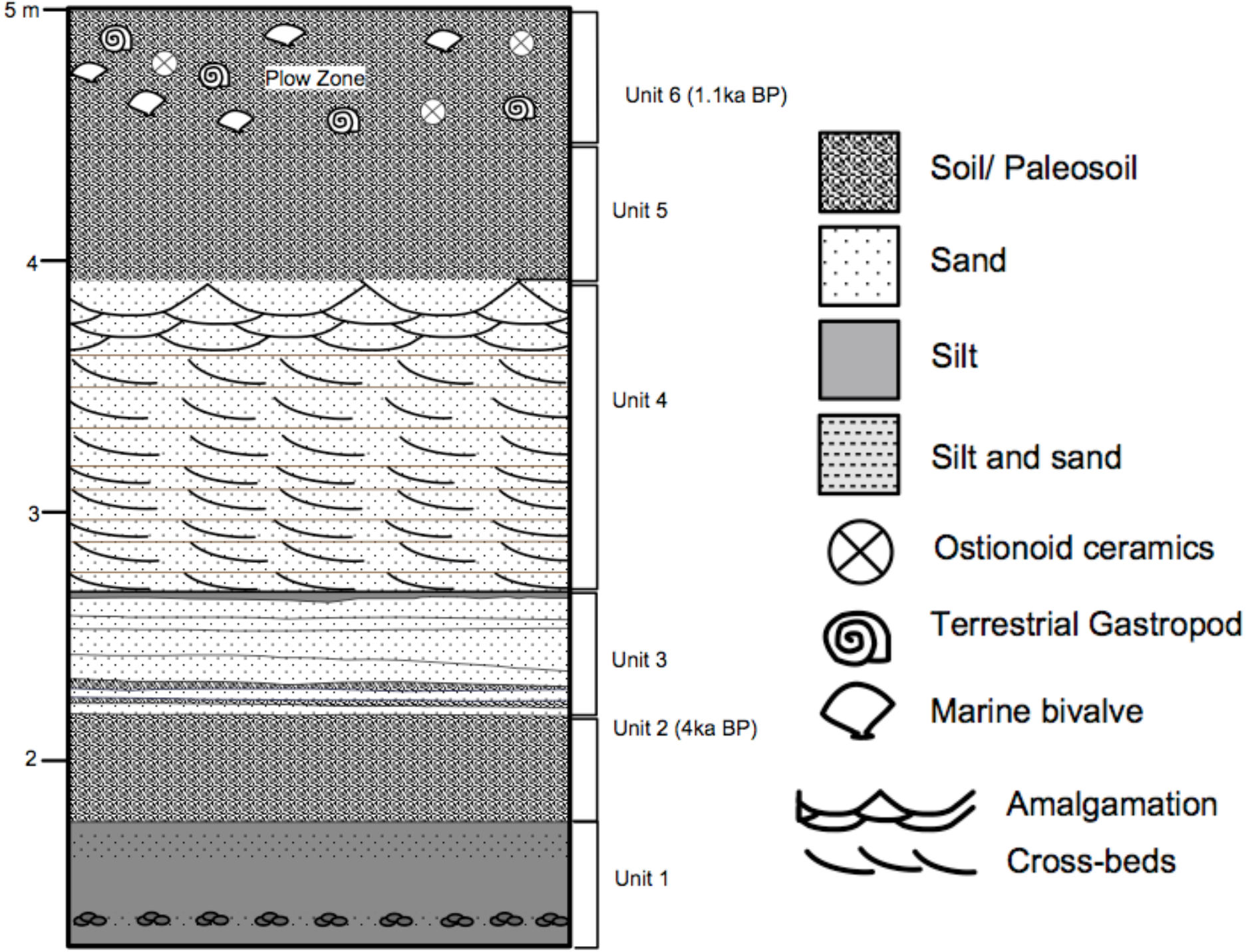
Ward, W.C., Scharlach, R.A., and Hartley, J.R., 1991, Controls on porosity and permeability in subsurface Tertiary carbonate rocks of northern Puerto Rico, in Gómez-Gómez, Fernando, Quiñones-Aponte, Vincente, and Johnson, A.I., eds., Regional aquifer systems of the United States—Aquifers of the Caribbean Islands: American Water Resources Association Monograph 15, p. 17–23;

Ward, W.C., Scharlach, R.A., and Hartley, J.R., in press, Geology of the North Coast ground-water province of Puerto Rico, in Renken, R.A., Ward, W.C., Gill, I.P., Rodríguez-Martínez, Jesús, and Gómez-Gómez, Fernando, Geology and hydrogeology of the Caribbean Islands aquifer system of Puerto Rico and the U.S. Virgin Islands: U.S. Geological Survey professional Paper 1419.

Hydrogeology modified from Renken, R.A., and Gómez-

Depósitos de 5 mil a 2,500 años de antigüedad, Santa Isabel, que sugieren un cambio del nivel del Mar en ese periodo.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


5 m
4
3
2
Plow Zone
Unit 6 (1.1ka BP)
Unit 5
Unit 4
Unit 3
Unit 2 (4ka BP)
Unit 1
Soil/ Paleosoil
Sand
Silt
Silt and sand
Ostionoid ceramics
Terrestrial Gastropod
Marine bivalve
Amalgamation
Cross-beds